US Army Corps of Engineers
Construction Engineering Research Laboratories

USACERL Technical Report 98/70
April 1998

Management of Herbaceous Seeps and Wet Savannas for Threatened and Endangered Species

by
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Wetland communities such as herbaceous seeps and wet savannas occur on military installations throughout the southeastern United States, usually as pockets of wet habitat within a matrix of drier longleaf pine woodlands. This larger community supports multiple uses, including the Department of Defense training and testing mission; threatened, endangered, and sensitive species (TES) conservation; and forest commodities production.

The overall objectives of this research were to compile known information, identify gaps in knowledge, and stimulate research efforts on the potential positive and negative effects of human activities on the plant communities that serve as high-quality habitat for TES in the southeast. The objectives of this work unit were to reduce duplication of effort in TES plant conservation by providing information that can be used to improve the ecological and economic effectiveness of TES habitat management.

This report provides ecological descriptions of these wetland communities, discusses land use practices and activities, and offers management recommendations.

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave Blank)*	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	April 1998	Final

4. TITLE AND SUBTITLE
Management of Herbaceous Seeps and Wet Savannas for Threatened and Endangered Species

5. FUNDING NUMBERS
Reimbursable Order
SERDP

6. AUTHOR(S)
Mary G. Harper, Ann-Marie Trame, and Matthew G. Hohman

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Construction Engineering Research Laboratories (USACERL)
P.O. Box 9005
Champaign, IL 61826-9005

8. PERFORMING ORGANIZATION REPORT NUMBER
TR 98/70

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Strategic Environmental Research and Development Program
ATTN: Conservation Program Manager
901 N. Stewart St., Suite 303
Arlington, VA 22203

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 words)
Wetland communities such as herbaceous seeps and wet savannas occur on military installations throughout the southeartern United States, usually as pockets of wet habitat within a matrix of drier longleaf pine woodlands. This larger community supports multiple uses, including the Department of Defense training and testing mission; threatened, endangered, and sensitive species (TES) conservation; and forest commodities production.

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14. SUBJECT TERMS
threatened species
endangered species
land management
ecological systems

15. NUMBER OF PAGES
86

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std 239-18
298-102

Foreword

This study was conducted for the Strategic Environmental Research and Development Program (SERDP) under the SERDP study "Regional Guidelines for Managing Threatened and Endangered Species Habitats." Brad Smith is Acting Executive Director, SERDP. The technical monitor was Femi Ayorinde, SERDP Conservation Program Manager.

The work was performed by the Natural Resource Assessment and Management Division (LL-N) of the Land Management Laboratory (LL), U.S. Army Construction Engineering Research Laboratories (USACERL) and by the Natural Resources Division (NRD), Environmental Laboratory (EL), U.S. Army Engineer Waterways Experiment Station (WES). The USACERL principal investigator was Ann-Marie Trame. The WES principal investigator was Chester Martin. Mary G. Harper was employed as a Research Associate under an interagency agreement with the U.S. Forest Service, Rocky Mountain Range and Forest Experiment Station, and Colorado State University. Ms. Harper was responsible for the ecological description of the communities, land use impact analyses, and recommendations for management of the community and plant species associated with the community. Matthew Hohmann (USACERL) made valuable contributions, especially in providing information about Coastal Plain depression ponds. Richard A. Fischer (WES) and Matthew Hohmann provided information on the requirements of animal species associated with these communities. The USACERL technical editor was Gloria J. Wienke, Technical Information Team.

COL James A. Walter is Commander and Dr. Michael J. O'Connor is Director of USACERL.

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1 Introduction

Background

Wetlands communities such as herbaceous seeps and wet savannas occur on military installations throughout the southeast, usually as pockets of wet habitat within a matrix of drier longleaf pine woodlands. This larger community supports multiple uses, including the Department of Defense (DoD) training and testing mission; threatened, endangered, and sensitive species (TES*) conservation; and forest commodities (e.g., timber, pine straw) production. Despite the primacy of the military training and testing mission, installations are required to maintain robust TES populations into the foreseeable future. Many of these populations, especially plants and amphibians, rely on wetland communities for survival.

Management approaches to protecting TES, other natural resources, and natural plant communities are often designed to address immediate and local problems (M. Imlay, Natural Resource Specialist, Army National Guard Bureau, professional discussion, 18 August 1995). Although this approach can be rewarding and effective for an individual installation, it precludes any organized understanding of land-use impacts, or sharing of lessons learned, and can sometimes lead to repeated, inefficient efforts to solve similar problems throughout a region of the country. Duplication of effort in Army land management needs to be reduced or eliminated.

This report is one product of an interlaboratory effort between the U.S. Army Construction Engineering Research Laboratories (USACERL) and the U.S. Army Engineer Waterways Experiment Station (WES) to generate habitat-based management strategies for TES on DoD lands in the southeastern United States (*Strategic Environmental Research and Development Program [SERDP] work unit "Regional Guidelines for Managing T&E Species Habitats"*; Martin et al. 1996). This effort is directed at developing strategies to manage TES and their habitats on a plant community basis, using methods that apply to multiple species and that apply across the southeastern United States. Any increase in understanding of the habitat

* The acronym "TES" will be used instead of "T&E Species" in this report to conform to standard DoD terminology. "Candidate Species" (former C1 species) are also defined as those plant and animal species that, in the opinion of the U.S. Fish and Wildlife Service (USFWS) or National Marine Fisheries Service, may qualify for listing as threatened or endangered pursuant to the Endangered Species Act; and "Species of Concern" (former C2 species).

requirements of listed TES will assist training and natural resource personnel in complying with the Endangered Species Act (ESA), while giving them the information they need to reduce restrictions on the military mission. Furthermore, the results detailed in this report suggest that a great deal of additional effort is required before the process will be guided by solid scientific information (as required by the ESA).

Objectives

The objectives of this research were to compile known information, identify gaps in knowledge, and stimulate future research efforts on the potential positive and negative effects of human activities on the plant communities that serve as high-quality habitat for TES plants in the southeastern United States.

This SERDP work unit, in particular, was undertaken to reduce duplication of effort in conservation of TES within the southeastern region. It is hoped that this review of information may be used to improve the ecological and economic effectiveness of TES habitat management. By understanding the ecological requirements of TES and the environmental resilience or sensitivity of TES habitats, installations acquire increased control over TES management and land use decisions.

Approach

To identify potential impacts, researchers reviewed the available literature and conducted interviews with community ecologists throughout the southeastern United States, with an emphasis on interviewing those people who have been involved in plant TES and plant community survey work on military installations. Site visits were made to military installations. Potential impacts were also discussed with military natural resources personnel, botanists, community ecologists, and military contractors, such as The Nature Conservancy (TNC) or state Natural Heritage Program (NHP) staff. Information also was gleaned from installation TES survey reports in which impacts and management were addressed. Land Condition Trend Analysis (LCTA) reports, Land Rehabilitation and Maintenance (LRAM) data, and academic and Federal agency literature on logging and recreational impacts to plant communities were also used.

Scope

Within the context of the larger DoD mission, TES populations can be maintained through the following framework: (1) identify mission requirements, (2) identify TES requirements, (3) identify ideal compromises for meeting both TES and mission requirements, and (4) pursue these compromises and develop realistic, workable compromises. The fourth step should be executed through professional management of TES populations, at the installation level, to reduce restrictions on the military mission. This document partially contributes to the total TES and land-management process. It provides information to assist in identifying the needs of TES (step 2), and perhaps will assist in identifying options for compromise as well (step 3). The content of this report is not intended to provide the "bottom line" for management of TES on military lands — only to provide information from literature review for the consideration of installation land managers.

This report focuses on plant communities because they provide habitat for multiple species. By managing for plant communities, DoD has the opportunity to conserve multiple TES simultaneously. Plant communities are less ambiguous entities than complete ecosystems, and have been described and cataloged for many decades by ecologists and biogeographers. They provide a useful basis on which to understand and manage the natural systems that support military training and other land uses.

Historically, pine flatwoods and sandhills dominated many upland areas of the southeastern Coastal Plain, forming a matrix in which other communities were embedded (Noss 1988). An earlier report from this SERDP work unit (Harper et al. 1997), provided management recommendations for the longleaf pine woodland communities of the region. This document covers the ecology of, impacts to, and management for imbedded (or "inclusional") wetland communities within the matrix. These wetland communities include herbaceous seeps (Figure 1), wet savannas (Figure 2) and Coastal Plain depression pond complexes (Figure 3). Herbaceous seeps and wet savannas are ecosystems dominated by grasses, sedges, and composites with an absence of a shrub layer or a tree canopy (although scattered trees or shrubs may occur). They are characterized by frequent fire, acidic soils, seasonal flooding or frequent saturation, and the occurrence of carnivorous plants (Frost, Walker, and Peet 1986; Penfound 1952). Coastal Plain depression pond complexes are complexes of small, isolated, seasonally or permanently flooded depressions in pinelands (Bridges and Orzell 1989; Florida Natural Areas Inventory [FNAI] and Florida Department of Natural Resources [FDNR] 1990; Schafale and Weakley 1990; Wharton 1978). These communities are considered together as a unit because they have similar hydrologic properties to seep and bog communities, and they provide important breeding sites for amphibians.

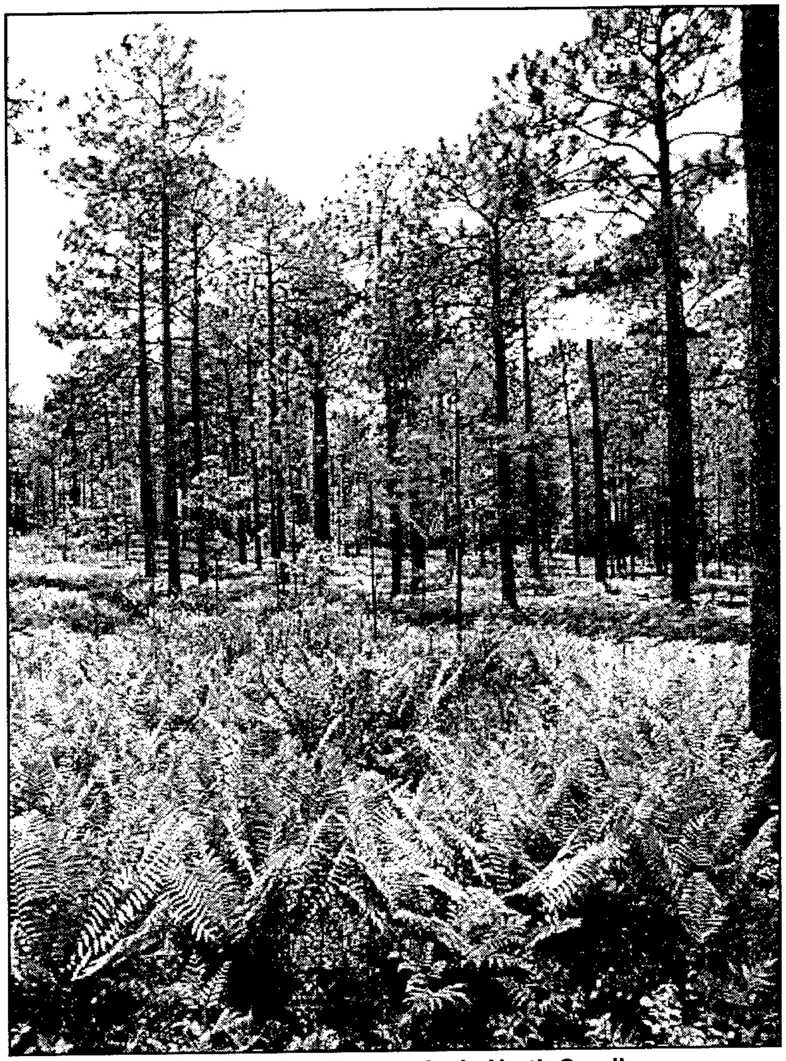

Figure 1. Example seepage community in North Carolina.

Figure 2. Example wet savanna community in Louisiana.

Figure 3. Costal Plain depression pond in Georgia.

These inclusional communities usually are not treated separately in literature syntheses regarding southeastern plant community classifications (e.g., Christensen 1988; Stout and Marion 1993; Myers and Ewel 1990). They are treated separately by this work unit because they support high species diversity, including several rare species, and they generally have unique soil and hydrologic characteristics, which make them more sensitive to human-related disturbance than their surrounding communities. Thus, they are characterized by additional management and protection considerations beyond those of the surrounding landscape. The range of these wetlands generally follows the distribution of longleaf pine in the southeastern United States (Figure 4). This distribution is closely aligned with the Southeastern Region designated by early efforts in the work unit (see Martin et al. 1996). Recommendations within this report are intended to be applied within this Southeastern Region.

Due to the scope of this report, specific management recommendations are intended to be considered only for areas that trainers and resource managers recognize and manage as endangered species habitat. Many of the most restrictive land-use recommendations are made for areas that are also recognized as protected wetlands due to their sensitive hydrology. These recommendations are not intended to be applied across entire DoD installations (e.g., on areas required for use as maneuver training zones).

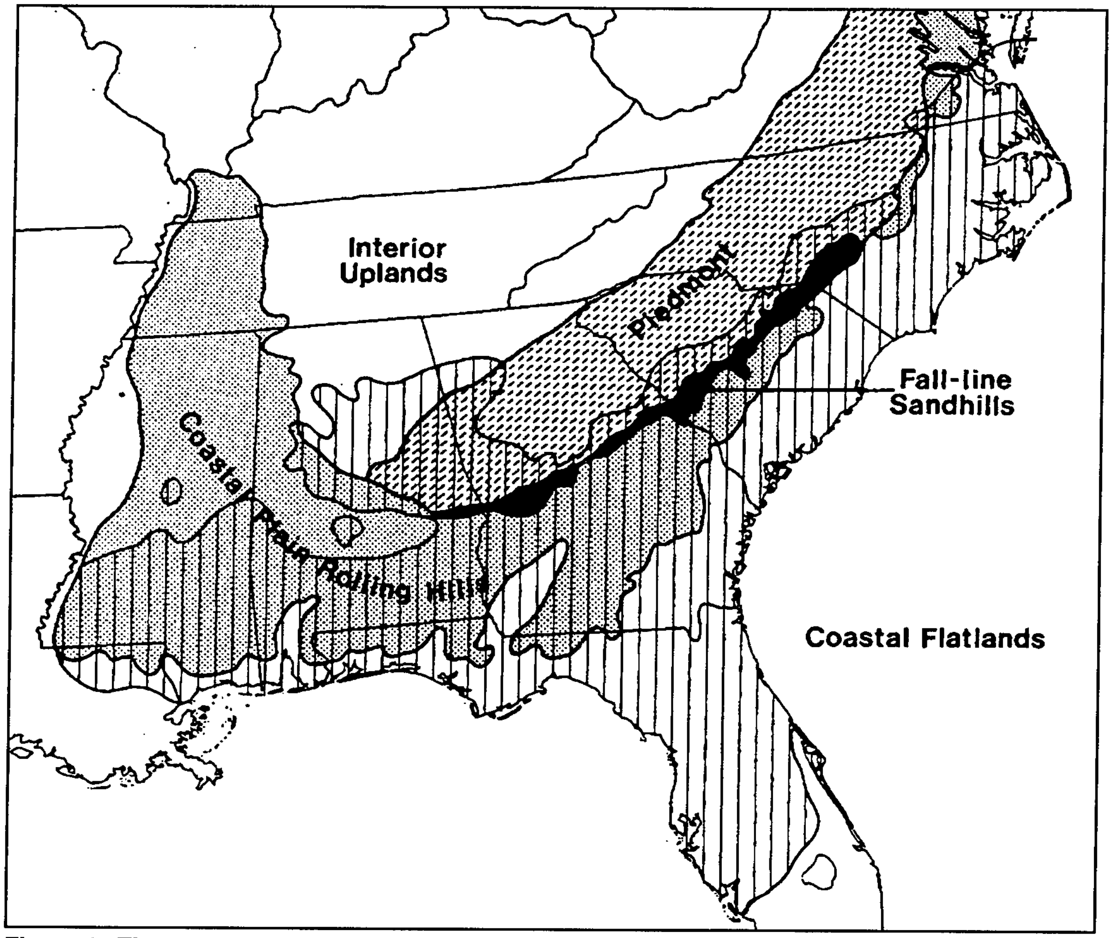

Figure 4. The range of longleaf pine-dominated communities (vertical lines) in the southeastern United States falls across several physiographic provinces.

Mode of Technology Transfer

This report is to be used by DoD natural resource policymakers, installation land managers, and the natural resource research community, in conjunction with associated documents produced by this SERDP work unit (e.g., Trame and Harper 1997; Harper et al. 1997) and by Trame and Tazik (1995), to (1) develop ecosystem-based approaches to describe natural communities and TES habitat in relation to military activities, (2) evaluate military-related effects on those communities, (3) develop community-based strategies for supporting both military land use and TES habitat management, and (4) develop management solutions for military impacts to natural communities when management for TES habitat is a priority for a particular location.

Results of this report will be presented at the annual SERDP Symposium. In addition, this and companion volumes have been identified for life-cycle technology demonstration and support in the Conservation Technology Infusion effort being developed under the Army's environmental science and technology process.

2 Ecological Description

Range

Current Distribution

These three communities occur throughout most of the Coastal Plain of the southeastern United States. Hillside seeps are most common from Texas to southwestern Georgia, and are also abundant along the western Florida panhandle. The largest wetland savanna areas are along the Gulf coast, but south Florida, Georgia, and the Carolinas also support considerable acreage (Folkerts 1991). Hillside seeps of the West Gulf Coastal Plain are generally less than 2 hectares (ha) in size, and many are less than 0.4 ha. Often, several occur within close proximity, forming a wetland complex. The largest wet savannas known in the West Gulf Coastal Plain are about 200 ha, but most remnants are between 4 and 20 ha (Bridges and Orzell 1989).

Distribution on Military Installations

The presence of herbaceous seeps, wet savannas, or Coastal Plain depression ponds has been documented on at least 21 installations in the southeastern United States (see Table 1).

Cross-Classification

The herb-dominated communities combined in this synthesis vary widely and are known by many names. As a group they have been referred to as grass-sedge-rush communities (Penfound 1952) and graminoid-dominated wetlands (Christensen 1988). The communities discussed herein may be divided into (1) those associated with slopes and occupying seeps, and (2) those occurring in depressed open areas with shallow water tables (wet savannas and small depression pond complexes).

Seepage communities have been called hillside bogs, pitcher-plant bogs, grass-sedge bogs, and green-heads (Smith 1988) in Louisiana; pitcher-plant bogs, Coastal Plain herb bogs, sphagnum bogs, and moist pine barrens in Georgia (Wharton 1978); hillside herb bogs and seepage herb bogs in South Carolina (Nelson 1986); and

sandhill seeps, hillside seepage bogs, and low-elevation seeps in North Carolina (Schafale and Weakley 1990).

Wet savannas have been called wet prairies, wet meadows, low marshes, moist savannas, plant lands (Penfound 1952), wet pine savannas, coastal meadows, pine barrens, and pine meadows (Smith 1988) in Louisiana; sphagnum bogs and moist pine barrens in Georgia (Wharton 1978); pitcher-plant flats and wet prairies in Florida (FNAI and FDNR 1990); pine savannas in South Carolina (Nelson 1986); and a zone of a small depression pond in North Carolina (Schafale and Weakley 1990; see Allard 1990). Cypress savannas, listed in classifications for Georgia and the Carolinas, appear to be intermediate in moisture between wet savannas and depression ponds (Nelson 1986; Wharton 1978; Schafale and Weakley 1990).

Coastal Plain small depression pond complexes are given the same name in North Carolina and are also called vernal pools (Schafale and Weakley 1990). In Louisiana, they are called flatwood ponds (Smith 1988). In Georgia, these are the small examples of cypress or gum ponds (Wharton 1978). In South Carolina, depression meadows, limestone sinks, and smaller swamp tupelo or pond cypress ponds are types of small depression pond complexes (Nelson 1986). In Florida, small depression pond complexes are called depression marshes and dome swamps (FNAI and FDNR 1990), and in Mississippi, they are named grady pond swamp forests (Allard 1990).

Environmental Factors

Topography and Hydrology

On the eastern Coastal Plain, hillside seeps are associated with the slopes of former dune systems (Folkerts 1991). On the western Coastal Plain, this community can be found on short steep slopes (10 to 30 percent), generally near midslope of the headwater of small ravines (Bridges and Orzell 1989). The soils of hillside seeps are saturated by discharge of ground water between an overlaying permeable sandy layer and a relatively impermeable lower layer (Folkerts 1991; Bridges and Orzell 1989). Seepage along slopes may also occur when downward movement of water is restricted by a completely saturated underlying layer (Plummer 1963; Smith 1988; Bridges and Orzell 1989; Folkerts 1991). Hillside seepage wetlands are hydrologically unique in that they are nearly constantly saturated, but never inundated (Bridges and Orzell 1989).

Table 1. Occurrence of herbaceous seeps, wet savannas, and small depression pond complexes on military installations in the southeastern United States.

State	Branch	Installation	Names in Document	Reference
AL	Army	Ft. Rucker	Seeps, bogs, wet meadows	Mount and Diamond (1992)
FL	Air Force	Avon Park Air Force Base (AFB)	Seepage slope, depression marsh, wet prairie	Howie (1994)
		Eglin AFB	Depression marsh, wet prairie, seepage slope	FNAI (1994a)
		Tyndall AFB	Wet prairie	FNAI (1994b)
		Yellow Water Weapons Area, Jacksonville Naval Complex	Drainage ditch	Environ. Services and Permitting, Inc. (1990)
	Army	Camp Blanding	Depression marsh	FNAI and The Nature Conservancy (TNC) 1995
		NAS Pensacola and Outlying Field, Bronson	Wet prairie	FNAI (1988)
GA	Air Force	Moody AFB	Flatwoods ponds, hillside seepages, isolated wetland complexes, wet prairie	TNC (1994)
	Army	Ft. Benning	Bogs, seeps	Gulf Engineers & Consultants, Inc. and Geo-Marine, Inc. (1994)
		Ft. Stewart	Sandhill seep, pine savanna, cypress savanna, cypress/gum ponds	TNC (1995)
	Marine Corps	Marine Corps Logistics Base (MCLB) Albany	Limesink ponds, forested limesink depressions	Georgia Department of Natural Resources (DNR) (1994)
LA	Army	Camp Villerie	Slash pine - cypress - hardwood	Teague, McInnis, and Martin (1995)
		Ft. Polk	Hillside bog, wooded seep	Hart and Lester (1993)
		Louisiana Army Ammunition Plant	Wooded seep	McInnis and Martin (1995)
MS	Army	Camp Shelby	Wet prairie - savanna	Dept. of the Army (1994)
NC	Army	Camp Mackall and Ft. Bragg	Little river seepage bank, sandhill seep, vernal pool	Russo et al. (1993)
		Military Ocean Terminal (MOT) Sunny Point	Small depression pond, pine savanna	M. Schafale, Community Ecologist, North Carolina Natural Heritage Program, professional discussion, 1994.
	Marine Corps	Marine Corps Base (MCB) Camp Lejuene	Depression meadow, small depression pond, vernal pool, pine savanna, cypress savanna	LeBlond, Fussell and Braswell (1994a, 1994b)

State	Branch	Installation	Names in Document	Reference
SC	Army	Ft. Jackson	Hillside herb bog, pine savanna	B. Pittman, Community Ecologist, South Carolina Natural Heritage Program, professional discussion, 1995.
	Navy	Naval Weapons Station (NWS) Charleston	Upland ponds/ depressions, grass-sedge savanna, sandy or moist longleaf pine (Pinus palustris) savanna	Porcher (1987)
VA	Army	Ft. A. P. Hill	Oligotrophic saturated herbaceous vegetation, oligotrophic semipermanently flooded herbaceous vegetation	Fleming and Van Alstine (1994)

Wet savannas once occurred over broad expanses of flat to gently rolling, imperfectly drained interstream areas along the outer Coastal Plain, occupying many areas except depressions, stream valleys, and hill rises (Bridges and Orzell 1989). They are characterized by little relief or slope. Precipitation is the principal source of water in wet savannas, as they usually do not receive groundwater input. Soils are seasonally saturated due to relatively impermeable underlying layers, which restrict downward movement of water. Because the hydroperiod length is dependent on the amount and frequency of rainfall, soil moisture varies within and among seasons. For example, wet savannas often dry out after rainless periods in the summer and fall, but may also become ponded in the lowest areas during the winter or after heavy rainfall (Bridges and Orzell 1989; Folkerts 1991).

On the eastern Gulf Coastal Plain and northern Florida peninsula, small depression ponds often occur in limesink complexes (Sutter and Kral 1994), and along other areas of the southeastern Coastal Plain in clusters of depressions (Wharton 1978; Bridges and Orzell 1989). Small depression ponds may be fed by either rainfall or groundwater, or both. Most are seasonally flooded, drying out during summer droughts. However, some may be permanently flooded in the center (Bridges and Orzell 1989; Schafale and Weakley 1990). Hydroperiod can vary markedly, ranging from as few as 50 days, to more than 200 days per year (FNAI and FDNR 1990). Karst ponds, which are fed by groundwater, show less short-term (seasonal) variation than depression wetlands fed by precipitation (Sutter and Kral 1994). Seasonal fluctuation in water levels and variation among years are the primary environmental factors structuring these plant communities (Bridges and Orzell 1989; Schafale and Weakley 1990).

Soils and Nutrients

Herbaceous seeps and wet savannas occur on mineral to shallow organic soils. Soils are typically sands, loamy sands, or sandy loams, with underlying layers having a high clay content (Folkerts 1991) that causes a shallow water table (Plummer 1963; Smith 1988; Bridges and Orzell 1989). Peat may also be present (Eleuterius and Jones 1969), but under natural conditions, frequent fires remove litter that might otherwise accumulate and form peat (M. Davis, Botanist, Waterways Experiment Station, professional discussion, June 1997 [hereinafter referred to as "M. Davis, June 1997"]). Peat formation is also limited by regular droughts (Folkerts 1991). The soils of herbaceous seeps and wet savannas are generally acidic (pH 4.0-5.5) and nutrient poor, with low nitrogen and phosphorus and exchangeable calcium levels (Rome 1988; Eleuterius and Jones 1969; Plummer 1963). Aluminum may occur at levels limiting to plant growth (Plummer 1963).

The substrate of depression ponds generally consists of acidic, nutrient poor, sandy soils with an underlying impermeable clay layer (Wharton 1978; FNAI and FDNR 1990; Schafale and Weakley 1990). Karst ponds also have a sandy substrate, but originate from subsidence in regions with an underlying limestone layer (Sutter and Kral 1994). The pH of karst ponds often depends upon the degree of connectedness to underground water sources. Karst ponds with a large ground water inflow may have a neutral pH, whereas those having only a weak connection are often acidic (Sutter and Kral 1994).

Nutrient dynamics in these wetlands is probably influenced by the occurrence of fire. In upland pine savannas and flatwoods, periodic burns have been shown to increase macronutrients (McKee 1982), without adversely affecting nitrogen and organic matter in surface soils (McKee 1982; Boyer and Miller 1994). More frequent (annual) burns can eliminate existing organic matter and lower available nitrogen, which is lost through volatilization (DeBell and Ralston 1970; Wells 1971; McKee 1982; Vose and Swank 1993). However, fire events also often introduce nitrogen replacement through fire-stimulated symbiotic and nonsymbiotic nitrogen-fixation (Wells 1971; Waldrop et al. 1987). In addition to fire, burrowing crayfish (*Fallicambarus* spp.) have also been speculated to play a role in nutrient dynamics in these wetland communities (unpublished information cited in Folkerts 1991).

Fire Regime

Herbaceous seeps and wet savannas require frequent fire to prevent invasion and dominance by certain woody species (Figure 5; Wharton 1978; Bridges and Orzell

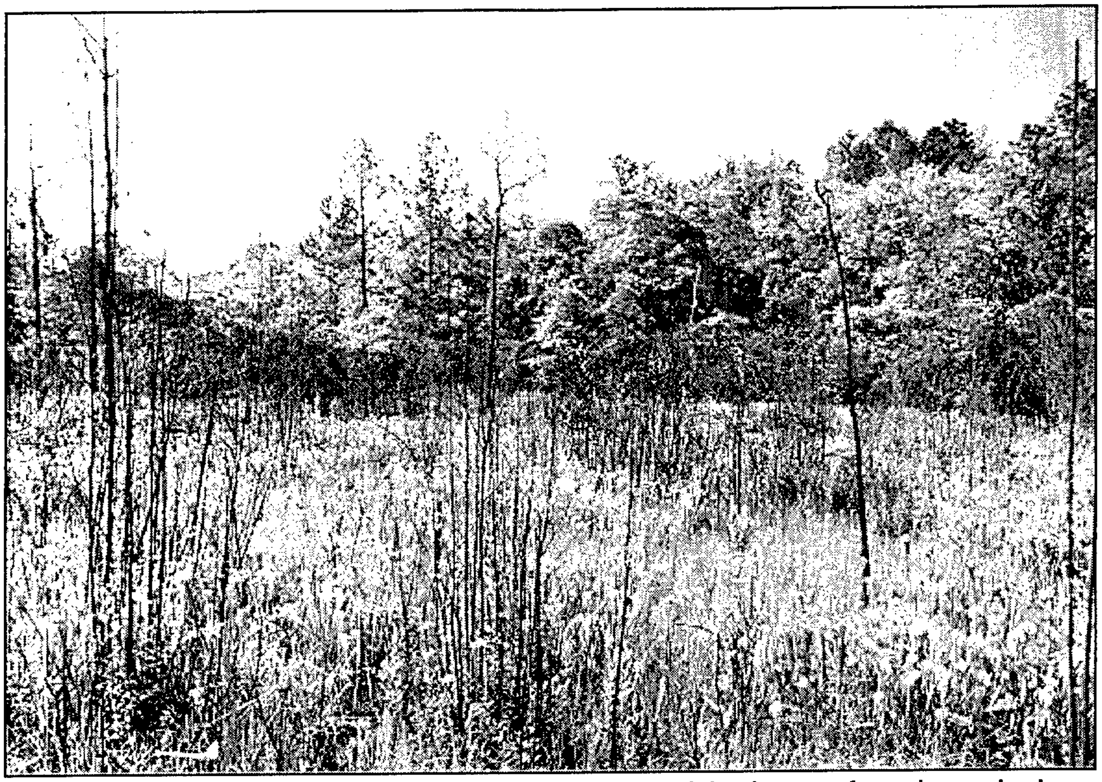

Figure 5. Frequent fires are required to prevent invasion and dominance of woody species in herbaceous seeps and wet savannas.

1989; Olson and Platt 1995). For example, Frost, Walker, and Peet (1986) noted that wet savannas in Alabama became dominated by shrubs and loblolly and slash pine when the fire return interval was increased from 1-3 to 5 years. Because these wetlands are inclusions in fire-dependent communities, fire frequency is determined by the fire regime of surrounding uplands. Fire return intervals may vary from 3 to 8 years in Georgia pitcher-plant bogs (Wharton 1978) to 1 to 5 years in herbaceous seepage bogs in Louisiana (L. Smith, Ecologist, Louisiana Natural Heritage Program, professional discussion, as cited in Patterson, Allard, and Landaal 1994) to 2 to 4 years in Florida wet prairies and seepage slope wetlands (FNAI and FDNR 1990). In presettlement times, natural fires probably occurred during early summer, since the highest frequency of lightning strikes occurs at that time (Komarek 1964; Chen and Gerber 1990; Robbins and Meyers 1992). Also, many native plant species are adapted to frequent early summer fires and dependent upon post-fire conditions (Frost, Walker, and Peet 1986; Platt, Evans, and Davis 1988; Streng, Glitzenstein, and Platt 1993; Brewer and Platt 1994; Glitzenstein et al. 1997).

Presumably, fire is important in maintaining depression pond communities, as it potentially restricts the development of peat, and the invasion of shrubs and trees (Wharton 1978; Sutter and Kral 1994). Because ponds dry during early summer droughts, growing season fires are most likely to burn through depression ponds

(Schafale and Weakley 1990). The frequency of fire in small depression ponds depends not only on the occurrence of fire in the surrounding upland habitat, but also on wetland hydroperiod. For example, ponds that are flooded for shorter periods of time may burn more frequently than those flooded for longer periods. For similar reasons, the outer edges of small depression ponds generally burn more frequently than the center (FNAI and FDNR 1990).

Physiognomy and Structure

Frequently burned herbaceous seeps and wet savannas have few shrubs (Peet and Allard 1993), and will either lack trees or contain widely spaced trees over a species-rich, graminoid-dominated ground cover. With fire exclusion, however, woody species are quick to invade. Trees found in herbaceous bogs and wet savannas often have comparably smaller diameters than woodland trees of the same age, due to the saturated, low nutrient soil conditions (MacRoberts and MacRoberts 1993a).

Hillside seeps have a graminoid-dominated ground cover and may also contain scattered broadleaf evergreen shrubs. On the wettest sites, both swamp tupelo and pond cypress may be present (Folkerts 1991).

The physiognomy of depression ponds varies with hydroperiod and fire frequency. Bridges and Orzell (1989) describe flatwoods ponds of the West Gulf Coastal Plain as dominated by tall (1.0 to 2.2 m) wetland grasses and sedges with a lower layer of semi-aquatic rhizomatous herbs, and scattered stunted wetland trees. On the Atlantic Coastal Plain, however, small gum and pond cypress ponds are typically dominated by wetland trees, such as black gum and pond cypress, with a shrub (*Ilex* spp.) and graminoid ecotone between wetland and upland habitats (Wharton 1978). Karst ponds typically have a sandy perimeter dominated by grasses and sedges, or in the Florida panhandle, by St. John's-wort (*Hypericum lissophloeus*), an evergreen shrub.

Commonly Associated Plant Communities

Herbaceous hillside seeps, wet savannas, and small depression ponds exist as inclusional communities within more extensive pine flatwoods or sandhills (FNAI and FDNR 1990; Schafale and Weakley 1990; Smith 1988). A wetland complex may also include bay forests (FNAI and FDNR 1990), coastal grasslands (Bridges and

Orzell 1989), cypress-dominated sloughs, depressions, and stream headwaters (M. Davis, June 1997). For example, in Louisiana, both seepage bogs and streamhead pocosins occur at stream headwaters. The relative area covered by each community is determined by fire frequency and intensity. Following a hot fire, the seepage bog increases in size after pocosin species are lost; after a fire-free period, the pocosin vegetation expands in area, and the bog shrinks (R. Stewart, Botanist and Ecologist, Kisatchie National Forest, Louisiana, professional discussion, 9 May and 24 July, 1995 [hereinafter referred to as "R. Stewart, 1995"]).

Successional Relationships

Fire frequency is a controlling factor in succession of these communities. Wet savannas may succeed to pine-shrub, pocosin-like communities (Christensen 1988), or mixed pine-hardwood forest in the absence of burning (Bridges and Orzell 1989). In the Atlantic Coastal Plain, the absence of burning can cause grass-sedge savanna to succeed to pocosin and then to gum-maple swamps; whereas, the return of frequent fire has been observed to have the reverse effect (Wells and Whitford 1976). Species diversity of graminoids, however, may be severely and permanently lost within 10 to 20 years of fire exclusion, such that a true reversal of succession is not possible (Frost, Walker, and Peet 1986). In the Gulf Coastal Plain, the absence of burning also may allow shrubs, as well as loblolly (*Pinus taeda*) and slash (*P. elliottii*) pines, to invade (Frost, Walker, and Peet 1986). Canebrakes are sometimes transitional seres between herbaceous bogs and pocosins, bays, and bottomland hardwood forests (Frost, Walker, and Peet 1986). Depression pond complexes can succeed to bottomland forest, or closed swamp forest, or pocosin in the absence of fire (Wharton 1978; FNAI and FDNR 1990; Bridges and Orzell 1989).

Biological Composition

Peet and Allard (1993) discussed vegetation of herbaceous seeps and wet savannas of the Atlantic and Eastern Gulf Coast. These communities usually have widely spaced pine trees (usually longleaf pine [*Pinus palustris*], though slash pine and pond pine [*P. serotina*] can also occur). Dominant grasses are bluestems (*Andropogon* spp.), wiregrass (*Aristida stricta* and *A. beyrichiana*), toothache grass (*Ctenium aromaticum*), muhly (*Muhlenbergia capillaris tricopodes*), and dropseeds (*Sporobolus* spp.). Interspersed among the grasses are numerous basal-rosette composites (e.g., *Balduina* spp., *Bigelowia* spp., *Carphephorus* spp., *Coreopsis* spp., *Helianthus* spp., *Solidago* spp.), sedges (e.g., fimbristylis [*Fimbristylis* spp.], beak-rushes [*Rhynchospora* spp.], nut-rushes [*Scleria* spp.]), insectivorous plants (e.g.,

sundews [*Drosera* spp.], Venus flytrap [*Dionaea muscipula*], pinguiculas [*Pinguicula* spp.], pitcher-plants [*Sarracenia* spp.], bladderworts [*Utricularia* spp.]), orchids (e.g., *Calopogon* spp., *Cleistes* spp., *Platanthera* spp., *Pogonia* spp., and *Spiranthes* spp.) and lilies (e.g., *Aletris*, *Lilium*, *Tofieldia*, and *Zigadenus*). Legumes are absent in herbaceous seeps and wet savannas; their abundance increases in better drained communities. For a detailed description of species occurring in herbaceous seeps and wet savannas of the Atlantic and Eastern Gulf Coastal Plain, see Peet and Allard (1993)

Harcombe et al. (1993) discussed vegetation of herbaceous seeps and wet savannas of the West Gulf Coastal Plain. These communities usually have widely spaced longleaf pine trees. They are characterized by a diverse herbaceous layer, often dominated by sedges (especially beak-rushes and nut-rushes), grasses (bluestem, little bluestem [*Schizachyrium* spp.], wiregrass, muhly, and in Louisiana, toothache grass), and composites. Communities that occur in uplands on slopes that receive seepage have a higher relative importance of pitcher-plants, other carnivorous plants, and sphagnum moss (*Sphagnum* spp.). Shrubs found in Louisiana bogs were those tolerant of wet habitat: wax myrtle (*Myrica cerifera*), red-bay (*Persea borbonia*), red choke-berry (*Aronia arbutifolia*), possum-haw (*Viburnum nudum*), and vaccinium (*Vaccinium corymbosum*; MacRoberts and MacRoberts 1990). For a detailed description of species occurring in herbaceous seeps and wet savannas of the West Gulf Coastal Plain, see Bridges and Orzell (1989) and Harcombe et al. (1993).

Biological composition of depression ponds varies with water depth and fire frequency. Scattered, stunted black gum (*Nyssa biflora*) and/or pond cypress (*Taxodium ascendens*) may form an open canopy. Other canopy associates include slash pine and red maple (*Acer rubrum*). The pond may be surrounded by shrubs, such as fetterbush (*Lyonia lucida*), titi (*Cyrilla* sp.), wax myrtle, and buttonbush (*Cephalanthus occidentalis*), in addition to species also found in the canopy. The herbaceous layer consists of emergent and wetland plants, including beak-rushes, sedges (*Carex* spp.), yellow-eyed grasses, hat-pins (*Eriocaulon* spp.), panic-grasses, St. John's-wort (*Hypericum* spp.), spikerushes (*Eleocharis* spp.), sundews, and chain ferns (*Woodwardia* spp.). Sometimes the center of the pond has permanent water and supports aquatic plants such as water lilies (*Nymphaea* spp.), spatterdock (*Nuphar* spp.), and bladderworts (Bridges and Orzell 1989; FNAI and FDNR 1990; Schafale and Weakley 1990; Wharton 1978).

Lists of prevalent species occurring in herbaceous seeps and wet savannas in Atlantic and Eastern Gulf Coastal Plain communities (Peet and Allard 1993) and Western Gulf Coastal Plain communities (Bridges and Orzell 1989) have been

tabulated, based on frequency of occurrence. In the Atlantic and Eastern Gulf Coastal Plain, the following species occur with 50 percent or greater frequency in herbaceous hillside seeps and wet savannas (Peet and Allard 1993): bluestems (*Aster dumosus*), rayless-goldenrod (*Bigelowia nudata*), tickseed (*Coreopsis linifolia*), toothache grass, dichanthelium (*Dichanthelium dichotomum ensifolium*), sundew (*Drosera capillaris*), fleabane (*Erigeron vernus*), eryngo (*Eryngium integrifolium*), boneset (*Eupatorium leucolepis*), gallberry (*Ilex glabra*), longleaf pine, meadow-beauty (*Rhexia alifanus*), and nut-rush (*Scleria pauciflora*). In the Western Gulf Coastal Plain, sedges, beak-rushes, sphagnum moss, bluestem grasses, wiregrass, toothache grass (in Louisiana), and pitcher-plants (Sarracenia alata) are among the most common herbaceous seep/wet savanna species (Harcombe et al. 1993). Yellow-eyed grass (*Xyris ambigua*), pipewort (*Eriocaulon decangulare*), blazing star (*Liatris pycnostachya*), colic-root (*Aletris aurea*), Barbara's buttons (*Marshallia tenuifolia*), beak-rush (*Rhynchospora gracilenta*), tickseed, hornpod (*Cynoctonum sessilifolium*), and polygala (*Polygala ramosa*) occur with 50 percent or greater frequency in the herbaceous hillside seeps and wet savannas examined by Bridges and Orzell (1989). The following species were found in more than 80 percent of the bogs studied by Nixon and Ward (1986) and, additionally, were recorded in at least two additional bogs by MacRoberts and MacRoberts (1988, 1993b), and/or were found with 50 percent or greater frequency in herbaceous hillside seeps or wet savannas by Bridges and Orzell (1989): cinnamon fern (*Osmunda cinnamomea*), red maple, sweet-bay (*Magnolia virginiana*), possum-haw, bamboo-vine (*Smilax laurifolia*), colic-root, Aster dumosus, Carex glaucescens, tickseed, sundew, pipewort, Eriocaulon texensis, eryngo, boneset, false hoarhound (*Eupatorium rotundifolium*), *Helianthus angustifolius*, blazing star, *Lobelia reverchonii*, Barbara's buttons, *Pinguicula pumila*, ettercap (*Pogonia ophioglossoides*), Polygala mariana, polygala, pale meadow-beauty (*Rhexia mariana*), pitcher-plant (*Sarracenia alata*), Scutellaria integrifolia, Spiranthes vernalis, Utricularia cornuta, primrose-leaved violet (*Viola primulifolia*), and yellow-eyed grass.

3 Ecological Quality

Biodiversity and TES

Herbaceous hillside seeps and wet savannas of the Southeastern Coastal Plain are very diverse and support several endemic species (Norquist 1985). The combination of low nutrients, acid soils, seasonally high water tables, and high fire frequency limits the establishment of woody species; these factors provide a unique habitat for wetland species tolerant of these extreme conditions (Folkerts 1991). The distinctive biota of herbaceous seeps and wet savannas includes more than 260 characteristic vascular plant species (Folkerts 1991). These communities support over 20 species of carnivorous plants (e.g., pitcher-plants, sundews, bladderworts, butterworts, and Venus flytrap), making them some of the most diverse carnivorous plant communities in the world (Folkerts 1990). Many plants associated with hillside seeps and wet savannas are under review by the U.S. Fish and Wildlife Service (USFWS) to determine if they should receive protection under the ESA (Norquist 1985). Several rare plant species have been documented in these communities on military installation lands (Table 2). In addition, pitcher-plants are the obligate associates of at least 12 insect species. Several crayfish, many of which have not been described scientifically, occur in these habitats (Folkerts 1990).

Table 2. Federally listed threatened, endangered, and former candidate plant species occurring in herbaceous seeps/wet savannas and small depression pond complexes on military installations in the southeastern United States.

Common Name	Scientific Name	Installation	Federal Status	Habitat/Community
Woody Plants				
Pondspice	*Litsea aestivalis*	MOT Sunnypoint MCB Camp Lejeune Fort Stewart	SAR	Bayheads, edges of sandy sinks, meteor ponds, and pocosins. Usually in very acidic, sandy, or peaty soils (Kral 1983).
Forbs				
Aster, Coyote-thistle	*Aster eryngifolius*	Eglin AFB	SAR	Bogs, pine savannas and flatwoods, borders of cypress-gum depressions (Godfrey and Wooten 1981).

Common Name	Scientific Name	Installation	Federal Status	Habitat/Community
Balduina, Purple	*Balduina atropurpurea*	Fort Stewart	SAR	Pitcher-plant bogs, wet pine flatwoods, and wet savannas with seasonal standing water (Smith 1994).
Bog-asphodel, Smooth	*Tofieldia glabra*	Camp Mackall and Ft. Bragg MCB Camp Lejeune	SAR	Moist ecotones between streamhead pocosins or herbaceous seeps and bogs and sandhills; also savannas and wet flatwoods, especially where they border on wetlands. Also can be found in open, disturbed habitats (e.g., roadside ditches, powerline rights of ways; Russo et al. 1993).
Bog buttons, tiny	*Lachnocaulon digynum*	Eglin AFB Ft. Polk	SAR	Seasonally or semipermanently saturated substrates, usually with little or no shrub or tree cover. Herbaceous bogs/seeps, wet flatwoods (Bridges 1986).
Boneset, Pine Barrens	*Eupatorium resinosum*	Camp Mackall and Ft. Bragg	SAR	Sphagnous bogs in pinelands and shrub bogs (Godfrey and Wooten 1981).
Butterwort, Godfrey's	*Pinquicula ionantha*	Tyndall AFB	T	Bogs, flatwoods depressions, adjacent ditches or drainage canals (Godfrey and Wooten 1981).
Butterwort, Chapman's	*Pinquicula planifolia*	Eglin AFB NAS Pensacola and outlying Bronson Field	SAR	In shallow water, margins of peaty ponds, bogs, boggy flatwoods, ditches, and drainage canals (Godfrey and Wooten 1981).
Coneflower, Bog	*Rudbeckia scabrifolia*	Ft. Polk	SAR	Hillside bog (Hart and Lester 1993).
Cowbane, Piedmont	*Oxypolis ternata*	MCB Camp Lejeune	SAR	Wet flatwoods, pocosins, herbaceous seeps and bogs, ecotones between flatwoods or sandhills and pocosins or herbaceous seeps and bogs, disturbed areas (Jordan, Wheaton, and Weiher 1995).
Cowlily, West Florida	*Nuphar luteum ulvaceum*	Eglin AFB	SAR	Fresh waters of rivers and streams, mostly "black" waters (Godfrey and Wooten 1981).
Crownbeard, Chapman's	*Verbesina chapmanii*	Tyndall AFB	SAR	Moist pine flatwoods. Confined to high hydroperiod, black, sandy-peaty soils; also at the edges of boggy sites (Kral 1983); bogs, grassy cypress depressions (Godfrey and Wooten 1981).
Flax, West's	*Linum westii*	Eglin AFB	SAR	Boggy depressions in pine flatwoods, margins of cypress ponds and depressions, St. John's-wort bogs, adjacent ditches (Godfrey and Wooten 1981).

Common Name	Scientific Name	Installation	Federal Status	Habitat/Community
Goldenrod, Carolina	*Solidago pulchra*	MOT Sunnypoint MCB Camp Lejeune	SAR	Wet or mesic flatwoods, and ecotones between flatwoods and adjacent pocosins or herbaceous seeps and bogs (Jordan, Wheaton, and Weiher 1995). Occasionally occurs in savanna ditches, savanna borrow scrape ecotones, powerline rights of ways, and roadsides (Russo et al. 1993).
Goldenrod, Spring-flowering	*Solidago verna*	Camp Mackall and Ft. Bragg	SAR	Wet flatwoods, and ecotones between flatwoods or sandhills and adjacent wetlands (Jordan, Wheaton, and Weiher 1995); numerous occurrences in disturbed areas (Russo et al. 1993).
Grass-of-Parnassus, Carolina	*Parnassia caroliniana*	Camp Mackall and Ft. Bragg	SAR	Prefers low, permanently moist drainages in open, herb-dominated grasslands (seeps and bogs, flatwoods, savannas, and ecotones between flatwoods or sandhills and adjacent wetlands); also found in disturbed areas (Russo et al. 1993).
Hartwrightia	*Hartwrightia floridana*	Avon Park AFB	SAR	Wet, open areas. Found in marshy grassland or among sphagnum in boggy swales (Ward 1979).
Lily, Panhandle	*Lilium iridollae*	Eglin AFB Camp Mackall and Ft. Bragg	SAR	Shrub zone of streamhead pocosins and their ecotones, and in sandhill seeps, in baygalls, wet flatwoods, seepage slopes, and edges of bottomland forests; typically in sandy peat or loamy soils that are saturated for at least part of the year (Russo et al. 1993).
Lobelia, Boykin's	*Lobelia boykinii*	MCB Camp Lejeune Ft. Stewart	SAR	Cypress savannas, depression meadows, clay-based Carolina bays and pine savannas (LeBlond, Fussell, and Braswell 1994a).
Loosestrife, Rough-leaved	*Lysimachia asperulaefolia*	MOT Sunnypoint Ft. Jackson	E	Ecotones between longleaf pine uplands (flatwoods and sandhills) and pocosins or herbaceous seeps and bogs in moist, sandy or peaty soils with low vegetation that allows for abundant sunlight in the herb layer. Also occurs in disturbed areas (Russo et al. 1993).

Common Name	Scientific Name	Installation	Federal Status	Habitat/Community
Meadow-beauty, Awned	*Rhexia aristosa*	MCB Camp Lejeune	SAR	Wet/mesic flatwoods, margins of ponds or depressions in pinelands, swamps; disturbed areas (Jordan, Wheaton, and Weiher 1995); Carolina bays, cypress savannas (LeBlond, Fussell, and Braswell 1994a).
Meadow-beauty, Panhandle	*Rhexia salicifolia*	Eglin AFB	SAR	Sandy shores or exposed shores of sandy limestone sinks, exposed bottoms of limestone-cypress ponds, coastal interdunal swales (Godfrey and Wooten 1981).
Monkeyface	*Platanthera integrilabia*	Ft. McClellan	SAR	Wet, flat, boggy areas at the head of streams or on seepage slopes. Usually associated with Sphagnum and usually grows in partial shade (Shea 1992).
Pitcher-plant, White-topped	*Sarracenia leucophylla*	Eglin AFB NAS Pensacola and outlying Bronson Field	SAR	Bogs, wet flatwoods, boggy borders of branch bays and cypress depressions, boggy areas by small streams (Godfrey and Wooten 1981). Areas that are wet almost year-round (TESII 1994).
Swamp Pink	*Helonias bullata*	Ft. A. P. Hill	T	Swampy, forested wetlands bordering meandering streams, headwater wetlands, sphagnous, hummock, dense, Atlantic white cedar swamps, blue ridge swamps, meadows, bogs, and spring seepage areas. Habitats are perennially saturated and rarely, if ever, inundated; the water table is at or near the surface and fluctuates only slightly. Soils are neutral to acidic. Canopy cover varies (USFWS 1991).
Venus Flytrap	*Dionaea muscipula*	Camp Mackall and Ft. Bragg MOT Sunnypoint MCB Camp Lejeune	SAR	Wet/mesic flatwoods, ecotones between flatwoods or sandhills and adjacent pocosins or herbaceous seeps and bogs, disturbed areas (Jordan, Wheaton, and Weiher 1995).
Water Milfoil, Piedmont	*Myriophyllum Laxum*	MOT Sunnypoint	SAR	Occurs in shallow water of natural ponds, especially sinkhole ponds, also in lakes, impoundments, beaver ponds, blackwater streams, backwaters, sloughs, drainage ditches, and canals (Russo et al. 1993).

Common Name	Scientific Name	Installation	Federal Status	Habitat/Community
Yellow-eyed grass, Drummond's	*Xyris drummondii*	Eglin AFB Tyndall AFB Ft. Polk	SAR	Bogs or boggy places where soil moisture is high, it is always in full sun. Pitcher-plant bogs in flatwoods are ideal. Also found in areas with clearcutting (Kral 1983). Moist acid sands, sandy peats, or sphagnous peats (Godfrey and Wooten 1981).
Yellow-eyed grass, Harper's	*Xyris scabrifolia*	Eglin AFB Tyndall AFB Ft. Polk Camp Mackall and Ft. Bragg	SAR	Moist to wet sandy peats (Russo et al. 1993). Pocosins, herbaceous seeps, and bogs and ecotones between these communities and flatwoods or sandhills (Jordan, Wheaton, and Weiher 1995).
Yellow-eyed grass, Quillwort	*Xyris isoetifoia*	Tyndall AFB	SAR	Moist sands or sandy peat of savanna bogs, flatwoods pond margins, and lakeshores (Godfrey and Wooten 1981).
Grasses, Rushes, and Sedges				
Dropseed, Pinebarrens	*Sporobolis sp. 1*	MCB Camp Lejeune	SAR	Wet flatwoods, savannas, small depression pocosins, and pond margins (LeBlond, Fussell, and Braswell 1994a).
Grass, Curtis' Sand	*Calamovilfa curtissii*	Eglin AFB	SAR	Most often found in ecotones between flatwoods and wetter areas that have wiregrass (Aristida stricta) as the most common species. Occurs as a band around ponds, in the zone between titi (Cyrilla racemiflora) and saw palmetto (Serenoa repens). In ponds surrounded by sandhill or scrub, it may fill the entire depression (Johnson 1993).
Grass, Southern Three-awned	*Aristida simpliciflora*	Camp Shelby	SAR	Moist pine woods (Small 1972).
Jointgrass, Piedmont	*Coelorachis tuberculosa*	Avon Park AFB Eglin AFB	SAR	Occurs in a depression marsh at Eglin AFB, FL (FNAI 1994a).
Panic grass, Hirst's	*Panicum hirstii*	MCB Camp Lejeune	SAR	At Camp Lejeune, NC, habitats are cypress savannas and depression meadows (LeBlond, Fussell, and Braswell 1994a).
Panic grass, Naked stemmed	*Panicum nudicaule*	Eglin AFB	SAR	Seep bogs, wet savanna; acid organic sands, peaty or silty muck of open stream or river bottoms (Kral 1983).
Rush, New Jersey	*Uncus caesariensis*	Ft. A. P. Hill	SAR	Open, usually sphagnous, groundwater-saturated habitats (Fleming and Van Alstine 1994).

Typical seep/savanna plants also have been found in disturbed habitats, such as drainage ditches, fire plowlines, and powerline rights of way (Russo et al. 1993). They also can occur in atypical habitats, such as cypress and tupelo swamps, bottomland hardwood forests, sand and gravel bars along streams, dense pocosins, and freshwater marshes. Although characteristic species may occur outside their natural habitat, these sites are usually reproductive sinks and cannot be considered areas in which seep or wet savanna species maintain themselves (Folkerts 1991).

Depression pond complexes often serve as important breeding and foraging sites for a variety of amphibians and birds (FNAI and FDNR 1990; Schafale and Weakley 1990; Wharton 1978). Many rare faunal species have been documented in these communities on military installation lands in the Southeast (Table 3). In addition, they may function as reservoirs for maintaining the water table (Wharton 1978).

The Use of Community Quality Assessment

To practice sound ecosystem management, several policy goals must be reconciled: the military mission, protection of TES, and consumptive land uses such as production of forest commodities. Decisions regarding land use priorities can be guided by site classification on the basis of ecological quality. Site quality initially can be assigned using baseline data, but should be augmented by a monitoring program that evaluates the effects of land use decisions. Determination of community quality has obvious benefits for TES conservation planning. Low quality communities do not provide the same habitat quality for TES as higher quality communities, and therefore should be treated differently in terms of protection, restoration efforts, and allowable land uses. Use of a quality ranking system for management purposes can assure that protection priority is given to highest quality TES habitat. Furthermore, use of a ranking system can assure that restoration activities are focused on communities that have the potential to become high quality TES habitat with minimum restoration efforts. Similarly, use of a quality ranking system can ensure that efforts are not wasted in the restoration of low quality communities. Finally, plant communities on installations are subject to multiple land uses, and utilization of a quality ranking system in combination with an assessment of impacts of various land uses can allow managers to determine which activities are appropriate in which communities, based on the potential to provide quality habitat for TES. The ranking system developed for Eglin AFB, FL, (Department of the Air Force 1993) is recommended for community quality assessments; details were described by Harper et al. (1997) and have been included in the Appendix. Management recommendations in this document are oriented toward the highest quality sites on military installations, unless specifically noted otherwise.

Table 3. Federally listed threatened, endangered, and candidate animal species, and species at risk occurring in herbaceous seeps/wet savannas and small depression pond complexes on military installations in the southeastern United States.

Common Name	Scientific Name	Federal Status	Habitat/Community
Mammals			
Florida Black Bear	*Ursus americanus floridanus*	SAR	Primarily bottomland hardwood forests, but has been documented using coastal flatwoods.
Squirrel, Sherman's Fox	Sciurus niger shermani	SAR	Primarily longleaf pine-turkey oak sandhills characterized by large, well-spaced pines and an understory of scattered or clumped oaks, although they may also be found in other open pine stands, mixed pine-hardwood forests, and in ecotones between forest types.
Birds			
Southeastern American Kestrel	Falco sparverius paulus	SAR	Found in open habitats, primarily in open pasture-like areas which include dead trees (i.e., snags). Also prefer open longleaf pine-turkey oak sandhill communities, agricultural/ mixed hardwood communities, pine flatwoods, grasslands, pastures, open sites within suburban and residential areas (e.g., golf courses, parks), edges of river bottoms, and along coastal regions.
Bachman's Sparrow	Aimophila aestivalis	SAR	Found in a variety of breeding habitats, including old deserted fields having dense grasses. Nests are typically in dry, open longleaf or shortleaf pine woods with a grassy herbaceous layer consisting of bluestems and forbs, and scattered shrubs or saw palmetto. In winter, scrub oak, open broom sedge fields, fencerows, and wet upland edges of river swamps and saltwater shores are used.
Red-cockaded Woodpecker	Picoides borealis	E	Inhabit open, mature pine woodlands maintained by low-intensity fire during the growing season. Optimal habitat is characterized as a broad savanna with a scattered overstory of large pine trees and a dense, diverse groundcover of grasses, forbs, and shrubs (Hooper et al. 1980, Jordan et al. 1995).
Reptiles and Amphibians			
Eastern Indigo Snake	Drymarchon corais couperi	T	Xeric uplands, pine flatwoods, wet prairies, and mangrove swamps. In southern Florida, common in riparian habitat, tropical hammocks, dry glades, and muckland fields. Outside peninsular Florida, snakes typically occupy upland ridges. In more northern portions of its range, the indigo snake is typically found in xeric, sandhill habitats with well-drained sandy soils. In Georgia, key habitat includes sand ridges associated with major coastal plain streams characterized by scrub oak, longleaf pine and turkey oak, or slash pine (P. elliottii)-dwarf oak areas, as well as clear-cut areas with windrows. During the spring and fall, indigo snakes in Georgia may use creek bottom thickets, upland pine-hardwood forest, mixed hardwood forest, and agricultural fields.

Common Name	Scientific Name	Federal Status	Habitat/Community
Pine Snake (Florida, Black, Northern)	Pituophis melanoleucus mugitus	SAR	Typically found in areas of sandy soil dominated by scrub pines and shrubs, flat sandy pine barrens, sandhills, and dry mountain ridges, longleaf pine sandhills, sandy old fields, turkey oak-pine forests. In Louisiana, both black and Louisiana pine snakes are restricted to longleaf pine forests and second growth longleaf pine-blackjack oak (Q. marilandica) associations. Louisiana pine snakes have been observed foraging in a seasonally dry, acid bog in Texas. The Florida pine snake is found in xeric sites, occurring primarily in longleaf pine-turkey oak woodlands, but also in sand pine scrub, pine flatwoods on well-drained soils, and old fields on former sandhill sites.
Gopher Frog (Dusky, Carolina, Florida)	Rana areolata spp.	C1, SAR	Gopher frogs breed in ephemeral to semi-permanent graminoid-dominated wetlands that lack large predatory fish. Also have been observed breeding in ditches and borrow pits, and have been heard calling from a recently re-filled, normally permanent wetland following an extreme drought. The reproductive habitat is best described as a circular or near-circular depression marsh, ranging from 0.4 ha to 33.5 ha. Pocosins and riparian stream corridors interlaced with longleaf pine communities are considered quality habitat in North Carolina.
Flatwoods Salamander	Ambystoma cingulatum	SAR	Breeding sites can include roadside ditches and borrow pits, typically encircled by a wiregrass-dominated graminaceous ecotone. Larvae occur in acidic, tannin-stained ephemeral wetlands (swamps or graminoid-dominated depressions) up to 9.5 ha, and are usually $\leq$0.5 m deep. The overstory is typically dominated by pond cypress (Taxodium ascendens), blackgum (Nyssa sylvatica var. biflora), and slash pine. Post-larval salamanders inhabit mesic longleaf pine-wiregrass flatwoods and savannas. The terrestrial habitat is best described as a topographically flat or slightly rolling wiregrass-dominated grassland having little to no midstory and an open overstory of widely scattered longleaf pine. High quality occurrences include several wetlands within a matrix of pine flatwoods and savanna.

Indicators of Community Quality

The presence or absence of some plant species is an indication of degradation. These indicator species have been noted for herbaceous seeps and wet savannas and small depression pond complexes.

Platt et al. (1990) listed the following species that, when present, indicate soil disturbance in hillside seepage bogs on the Kisatchie National Forest (NF), LA: dog-fennel (*Eupatorium capillifolium*), common golden-rod (*Solidago canadensis*), rag-weed (*Ambrosia* spp.), and others. *Lespedeza, Desmodium, Hypericum,* bluestems,

and *Rhus* spp. indicate fertilization on the Kisatchie NF; *Hypericum* also indicates sedimentation at the same location (R. Stewart 1995).

Platt et al. (1990) listed the following disturbance-intolerant species whose disappearance or reduction indicates soil disturbance: slender bluestem (*Schizachyrium tenerum*) and three-awn grasses (*Aristida* spp.). On the Kisatchie NF, the presence of toothache grass and pitcher-plants indicate appropriate bog hydrologic conditions (R. Stewart 1995).

Wells and Skunk (1928), who conducted an ecological study of a North Carolina herbaceous bog, described rose pogonia (*Pogonia opohioglossoides*) as being a bog species that is "kept out of the more favorable hydroperiod region by competition." This suggests that the presence of rose pogonia may indicate stressful edaphic conditions to which bog species are adapted. Wells and Skunk (1928) also noted that during a drought *Andropogon scoparius* (*Schizachyrium scoparium*, little bluestem), a species more common in the upland ecotone of the bog, "made a mass entry on the area. The plants occupied the bare intertussock areas." This suggests that an increase in little bluestem dominance within the bog may indicate drying out of the bog.

Folkerts (1982) listed several species that are essentially restricted to the Gulf coast pitcher-plant bog habitat: rayless goldenrod, stokesia (*Stokesia laevis*), death camus (*Zigandenus glaberrimus*), meadow-beauty, yellow fringeless orchid (*Habenaria integra*), rose-gentian (*Sabatia campanulata*), polygalas, yellow-eyed grasses, pipeworts, and most notably, several species of carnivorous plants, including pitcher-plants. Two lycopods (*Lycopodium* spp.) are also prominent.

Norquist (1985) listed several species that are endemic to savannas and bogs of the southeastern United States. These included carnivorous plants, including pitcher-plants, sundews, bladderworts, butterworts, and Venus flytrap. Also included were several species of yellow-eyed grasses, pipeworts, bog buttons (*Lachnocaulon* spp.), polygalas, beakrushes, fringed orchis' (*Habenaria* spp.), grass-pinks (*Calopogon* spp.), redroot (*Lachnanthes caroliniana*), white-topped sedge (*Dichromena colorata*), golden-crest (*Lophiola americana*) and toothache grass.

Christensen (1988) listed several species for wet savannas occupying ecotones between mesic savannas and shrub bogs: sundew (*Drosera intermedia*), tickseed (*Coreopsis falcata*), beak-rush (*Rhynchospora chalarocephala*), hog-fennel (*Oxypolis filiformis*), bay blue-flag (*Iris tridentata*), three-awn grass (*Aristida affinis*), and anthaenantia (*Anthaenantia rufa*). Shrub bog species such as titi (*Cyrilla*

racemiflora) and vaccinium also may be common (Christensen 1988). However, shrub dominance may indicate fire suppression or other disturbances.

Bridges and Orzell (1989) listed the following species as being restricted to West Gulf Coastal Plain flatwoods ponds, which suggests that these species are indicative of the community: milkweed (*Asclepias lanceolata*), sedge (*Carex verrucosa*), pipewort (*Eriocaulon compressum*), ludwigia (*Ludwigia sphaerocarpa*), beak-rushes (*Rhynchospora cephalantha, R. tracyi*), rose-gentian (*Sabatia dodecandra*), nut-rush (*Scleria baldwinii*), bladderwort (*Utricularia purpurea*), and yellow-eyed grasses (*Xyris fimbriata* and *X. smalliana*).

High Quality Examples

At Camp Blanding, FL, several indicators of high quality (Type I, see Appendix) depression marshes were noted. In these communities, St. John's-wort covered nearly 100 percent of the depression; shrubby vegetation other than St. John's-wort was restricted to the edge. Soil and vegetation disturbance (e.g., off road vehicle [ORV] trails and firebreaks) was absent. In addition, planted pines were not present in the ecotone (FNAI and TNC 1995).

At Eglin AFB, FL, high quality (Type I) depression marshes were noted for having little or no physical disturbance to either soil or vegetation caused by humans (e.g., ORV trails and firebreaks) or exotic animals. In addition, herbaceous cover was dominant, covering approximately 75 percent of the community. Shrubby vegetation, if present, was generally restricted to the outer edges.

Cooter's Bog in the Vernon District of the Kisatchie NF, LA, exhibited higher species richness than 11 other Louisiana bogs studied (MacRoberts and MacRoberts 1993b). One hundred thirty-five taxa representing 88 genera and 45 families were identified over a 9-month period in 1992. High overall species richness was reflected within small-scale plots as well; a 25-square-meter plot contained 36 species while 2 1-square-meter plots contained 26 and 27 species. Species richness was 20 percent higher than other sites studied. It is thought that the relatively large size of Cooter's Bog (approximately 3.2 ha) and its southerly location, within the range of many species that are not found farther north, may contribute to the high species diversity seen (MacRoberts and MacRoberts 1993b).

Intermediate Quality Examples

Intermediate quality depression marshes at Camp Blanding (Type II) were degraded due to fire suppression or physical disturbance to soil and vegetation. In addition

to the species listed in the high quality examples, widely scattered individuals of slash pine may have occurred due to fire suppression or planting. Other weedy small trees and shrubs that may have occurred were titi, myrtle-leaf holly, gallberry, and wax myrtle. Herb cover usually was less than 75 percent. Anthropogenic disturbance to soil and vegetation (e.g., fire breaks, drainage ditches, ORV ruts, trash, and feral hog damage) was evident. Important field indicators of Type II quality were the presence of shrubs and trees within the site, evidence of disturbance to soil and vegetation, and presence of firebreaks along the perimeter (FNAI and TNC 1995).

Intermediate quality depression marshes at Eglin AFB, FL, exhibited weedy species, including buckwheat tree, greenbriar, broomsedge, and dog fennels. Imported fire ants may have been present. Shrubby vegetation was dominant or codominant, and there was evidence of disturbance (FNAI 1994a).

4 Land Use Practices and Activities

Although herbaceous seeps and wet savannas are not specifically targeted for land uses such as grazing, military training, or forestry, their position within the larger longleaf pine woodland landscape exposes them to the same practices conducted in sandhills and flatwoods communities. Thus, many areas currently support multiple land uses. This chapter describes the management practices and multiple land uses that may occur within herbaceous seeps and wet savannas on military installations. Practices associated with agriculture, fire management, forestry, construction activities, and military training have the potential to alter the quality of habitat for TES, which currently depend on remnants of these communities (see Chapter 5, Impacts and Management Recommendations). Major activities are discussed in the following paragraphs.

Fire Management

Before the 1920's, herbaceous seeps and wet savannas burned frequently during the growing season as a result of fires ignited by lightning strikes in the larger longleaf pine sandhills and flatwoods landscape. In addition, prescribed fires were often set over large areas during the dormant season for game management purposes. Most of the range of longleaf pine came under effective fire suppression between 1920 and 1950, leading to the development of a dense forest (Frost 1993). On military installations, frequent fire continued to occur throughout the year in artillery impact areas, with occasional accidental and/or prescribed fires in other areas. Fire may increase soil erosion in the short term (through removal of vegetation and the use of fire control plowlines) but it restores conditions for the herbaceous plant species associated with high quality herbaceous seep and wet savanna communities (Haywood, Martin, and Novosad 1995). Today's DoD installation managers must, therefore, balance the need to control erosion with the need to sustain fire-dependent communities.

As a means of accidental fire suppression and to control prescribed fires, managers have created plowlines throughout natural communities. Creating plowlines involves removing vegetation to the mineral soil layer. Historically, plowlines often were placed in ecotones between sandhills or flatwoods and adjacent wetlands

(Frost, Walker, and Peet 1986), disrupting the wetland and ecotonal vegetation, soil, and hydrology.

Current fire management practices in herbaceous seeps and wet savannas are discussed in detail in Chapter 5. Fire management includes the use of prescribed fire, and the use of plowlines, surfactant foams, and natural wetland barriers to control fire intensity and spread.

Agricultural and Forestry Practices

Agricultural and forestry practices include site preparation activities such as disking and chopping, ditching and draining, bedding, and fertilization. Disking is used to ameliorate soil compaction and improve drainage. Steel blades that penetrate deep into the soil are used to cut and break small stems and roots. Disks are most frequently pulled by crawler tractors, but rubber-tired skidding tractors also may be used. Chopping is used to sever standing vegetation and involves rolling a heavy steel drum studded with radially oriented cutting blades across a site. Drums can be pulled by an articulated rubber-tired skidder or crawler tractor. Ditches and drains are installed to increase water drainage and soil aeration to enhance tree growth. Bedding is another practice to improve drainage. It involves forming mounds of soil using bedding plows pulled by crawler tractors or rubber-tired skidders (Lowery and Gjerstad 1991); trees are then planted on the mounds. Fertilization of soils can improve understory plant growth and production in the short term, but at least one study has found fertilization to be largely unnecessary in areas where fire was controlled (Haywood and Thill 1995).

Activities related to the production of commodities such as logging, turpentining (the removal of gum from live pine trees), stumping (the removal of stumps from the ground usually with crawler tractors), and pinestraw raking (the harvest of fallen pine needles either by hand-raking or tractor-drawn hay rakes and balers) occurred and all except turpentining still occur in longleaf pine woodlands, including some seeps and savanna areas. Logging did not affect the forest significantly until 1870. Between 1870 and 1930, intensive logging removed virtually all remaining virgin forest in the South (Frost 1993). From approximately 1920 to the present, logged forests were converted to plantations, and species such as loblolly and slash pine were planted (Frost 1993). Contemporary logging is characterized by the use of heavy machinery (wheel or crawler tractors), the creation of haul roads, and use of log decks and skid trails (Hatchell, Ralston, and Foil 1970). Today, many different tree harvesting cuts are used (Table 4). Turpentining occurred historically from 1834 to approximately 1890. Most mature trees were used for turpentining, which

Table 4. Tree harvesting methods used in the southeastern United States.

Kind of Cut	Description
Clearcut	Timber harvest in which an entire stand of trees is cut.
Salvage cut	Harvesting dead or dying trees or those in danger of being killed to save their economic value (Farrar 1993).
Seed-tree cut	Forestry practice in which 5 to 10 residual trees per acre are left on the site after harvest for the purpose of natural regeneration (Boyer 1993).
Selection cut	Forestry practice involving creation and maintenance of an uneven-aged stand. Individual trees or small groups are harvested at periodic intervals (cutting cycles) of 5 to 15 years based on species, physical condition, and degree of maturity (Farrar 1993).
Shelterwood cut	A silvicultural system in which mature trees are removed, in a series of cuts, to achieve a new even-aged stand under the shelter of remaining trees.
Irregular shelterwood cut	Harvesting a portion of trees at rotation age, leaving a substantial number of residual trees scattered across the stand throughout succeeding rotation(s) (Rudolph and Conner 1996).

involved cutting the bark from the tree and installing a tap. This practice weakened the trees to the extent that subsequent fires or winds often killed them (Frost 1993).

Pine beetle control practices are often necessary to protect forest health and minimize economic impacts to the timber industry. Controls range from synthetic pesticide application and selective removal of infected and adjacent trees, to the emerging use of biopesticides (Strom, Goyer, and Hays 1995). Pine beetle infestations generally range in size from individual trees to several hectares (K. Robertson, Plant Ecologist, USACERL, professional discussion 1996).

The removal of stumps, snags, and other woody debris associated with stumping, road construction, pest control, and other traditional forestry operations have the potential of negatively affecting biodiversity. Researchers increasingly are recognizing and documenting the biological importance of coarse woody debris in southern forest ecosystem structure and function (McMinn and Crossley 1993; Harvey and Pimentel 1996), both terrestrial and aquatic (Wallace, Grubaugh, and Whiles 1993), in addition to negative consequences associated with woody debris loss (Harvey and Pimentel 1996). Specifically, McMinn and Crossley (1993) provide selected papers asserting the role of coarse woody debris in maintaining regional biological diversity in addition to specific consideration of its importance in seedling

recruitment and maintenance of healthy and diverse fish, invertebrate, bird, mammal, herpetofauna, and soil mite communities. The ability of altered longleaf pine communities on installations to provide TES habitat in addition to training and testing opportunities varies considerably. Lands that have been ditched, drained, and bedded, or subjected to severe mechanical disturbance may no longer be able to support native groundcover and may require significant rehabilitation efforts to restore. Regardless of disturbance to groundcover, conversion to plantations can lead to the development of a dense canopy of pines that eliminates habitat for the shade-intolerant plant species characteristic of the herb layer in natural communities.

Silvicultural alterations to habitat may affect listed animal species as well as herbaceous plants. Reported examples include the loss of habitat for pine snakes (Jordan 1995) and flatwoods salamanders (*Ambystoma cingulatum*; Means, Palis, and Baggett 1994); reduction in groundcover vegetation (e.g., forage availability) for gopher tortoises because of shading by the dense overstory (Diemer 1989); development of stands that are not burned frequently enough or have trees that are too densely stocked for eastern indigo snakes (USFWS 1982); and development of unsuitable foraging habitat for southeastern American kestrels (*Falco sparverius paulus*) (Bohall 1984). Variations in modern silvicultural practices, such as the use of irregular shelterwoods, may be compatible with red-cockaded woodpecker management, although this continues to be debated by scientists (Rudolph and Conner 1996). Managing to protect TES and unique natural communities on installations may require less emphasis on traditional silvicultural practices in the future.

Activities not related to forestry that affect herbaceous seeps and wet savannas include livestock grazing, creation of wildlife food plots, and conversion to agricultural lands. According to Frost (1993), hogs, cattle, mules, sheep, and goats have grazed the southeastern landscape since European settlement. Feral hogs (*Sus scrofa*) have had the greatest effect on tree species, preventing regrowth of longleaf pine. Hogs reached high densities throughout the range of longleaf pine in 1860, and still run wild in some areas. Open range grazing ended between 1880 and 1930, and longleaf pine regenerated on many of these areas before the era of fire suppression (Frost 1993). Wildlife food plots require the artificial establishment of introduced or cultivated species for the purpose of feeding increased populations of game species. This involves clearing native vegetation, often in openings created by logging practices. Conversion to farms supporting agricultural species also occurred in herbaceous seeps and wet savannas. Some mixed pine-hardwood communities in existence today developed when agricultural fields were left fallow (Means and Grow 1985).

Military Training Activities

Dismounted military training occurs during portions of training exercises when soldiers are on foot. Activities may include patrolling, navigation, marching, and occupational exercises (bivouacking) without vehicles. Effects on natural resources can be similar to those generated in campgrounds or along hiking trails. Land navigation exercises are non-mechanized, orienteering exercises in which individual soldiers or small groups must use a map in unfamiliar terrain to reach a specified location. Platoons and companies must master the skills of scouting and patrolling in units of 33 to 120 soldiers. They are expected to operate in any terrain and under any weather conditions (Michigan Department of Military Affairs [Michigan DMA] 1994). Infantry units are rapidly deployed in a dispersed pattern throughout a large area. Their mission is to conduct synchronized but decentralized operations (Army Field Manual 71-100, 1990).

Occupation of land (bivouacking) occurs anytime a unit stops to set up security, rest soldiers or equipment, construct fighting positions, camouflage vehicles and equipment, or stay in one place for any length of time. These actions have the potential to damage sites through vehicle activity, foot traffic, and digging (Department of the Army 1993). Firing points and any other areas where troops gather can experience the same damage.

Mechanized and armored units are dominated by heavy tracked vehicles. They provide mobile, well-protected firepower. They are deployed over large open areas where long-range weapons with flat trajectories can be shot. Movement can occur anywhere on the terrain, up and down hills, and in some cases, through streams and ponds. Since the terrain is used for protection, maneuvers such as avoiding open space, avoiding open or high ground, or using depressions for concealment must be practiced (Army Field Manual 7-7, 1985). During offensive operations, the units' mission includes rapid concentrations of power, so mobility is extremely important, and this requires large expanses of open terrain (Army Field Manual 71-100, 1990). Mechanized and armored training cause damage due to "violently executed vehicle movement" and sustained weapons fire (Michigan DMA 1994).

The modern soldier relies on battlefield terrain to provide concealment and protection. The terrain is used and modified by all units. For example, soldiers dig fighting positions such as foxholes and tank pits. Engineers must know how to reduce enemy obstacles, create friendly obstacles, and protect soldiers from enemy fire by altering the terrain (Army Field Manual 5-100, 1988). Engineer units use modified tanks, road graders, bulldozers, cranes, backhoes, High Mobility Multi-Purpose Wheeled Vehicles (HMMWV, more commonly known as "Humvees") and

front-end loaders. Engineer activities require movement of massive amounts of soil. Even the deepest root systems of plants can be damaged during these activities (Trame 1997).

An Army division includes dozens of support and service units. Signal units must plan, provide, and maintain communication systems between command posts and subordinate units. They use light to medium-sized trucks. Medical corps train in field hospital conditions. Most specialized units use wheeled vehicles, but their potential for impacting natural resources is minimal compared to fighting operations. Table 5 lists some military training activities that can potentially alter natural communities.

Table 5. List of military activities that can potentially alter natural communities on military installations in the southeastern United States.

ACTIVITY	DESCRIPTION
Training on foot	In file on established route; moving cross-country; escape and evasion training
Use of tracked tactical vehicle	In file on established route or moving cross-country; moving cross-country; crossing stream; tactical maneuver training
Use of wheeled tactical vehicle	In file on established route or moving cross-country; moving cross-country; crossing stream; tactical maneuver training; transport of POL or supplies cross-country
Military watercraft	In coastal or inland waters, beaches, and dune habitats
Airborne operations	Air drop; firing airborne small arms, or medium and heavy weaponry; hover aircraft
Munitions	Firing small arms, or medium and heavy weaponry; firing missiles and rockets; use of incendiary devices
Potential pollution	Use of smoke products, gases
Earthmoving activities	Construction of obstacles, fortifications, or emplacements; engineer heavy equipment operations
Miscellaneous activities	Firefighting, camouflage, bivouacking, bridge-building, assembly/staging activities

5 Impacts and Management Recommendations

Management information is based on literature review, contacts with experts, and guidelines provided in installation reports. Information on habitats (see Tables 2 and 3) and management for rare plant species was gathered from USFWS Recovery Plans, Element Stewardship Abstracts provided by TNC; Jordan, Wheaton, and Weiher (1995); Godfrey and Wooten (1979, 1981); Kral (1983); Small (1972); and Ward (1979).

Landscape-Level Management

Inclusional wetland communities should not be managed separately from the pine woodland landscape in which they exist. They are dependent on processes that occur across the larger landscape, and will shift position within the landscape over time. For these reasons, management should be directed at maintaining them as sensitive features of the overall landscape. For example, management activities such as prescribed burning are most effective if carried out (or at least planned and coordinated) on a landscape scale. In addition, decisions based on the quality of a wetland may be influenced by its context in the larger landscape. Restoration of a Type III seepage community may be worthwhile if it exists in a Type I (see Appendix) pine woodlands, because landscape-level processes are likely to exist, and conservation of upland and wetland TES species can be accomplished within a functioning landscape unit (perhaps a large watershed). Similar criteria can be used to minimize fragmentation or restore corridors in areas where important TES habitats are already fragmented.

Fragmentation and Land Conversion

Impacts

It is estimated that over 97 percent of herbaceous seeps/wet savannas once found on the Southeastern Coastal Plain no longer exist. Hillside bogs have been converted to farm ponds, and savannas have been drained and converted to pine plantations and pastures (Norquist 1985). Land conversion for plantation forestry reduces

habitat for TES plant species in several ways. In addition to the damage caused by intentional drainage, even-aged plantation stands cast heavy shade on light-demanding bog species. Eventually, a thick layer of pine needles accumulates on the ground, killing any seedlings or small plants (Folkerts 1990). In addition to direct losses from such changes, many herbaceous seeps and wet savannas have been lost through succession resulting from fire exclusion (Norquist 1985).

Bog and seep communities tend to be small and rare in landscapes, so species dependent on such wetlands may have small population sizes, and may depend on gene flow or recruitment from other wetland sites in the landscape. Therefore, small wetland populations may be at increased risk of extinction if they are isolated from other wetland sites. Isolation may also lead to changes in plant species composition or possibly a decrease in native wetland species richness. For example, small isolated bogs were found to have a larger component of species with light, wind-dispersed seeds than larger, well-connected wetlands (Pearson 1994). Increased distances between habitat patches will affect animals as well. Species able to disperse over greater distances of altered habitat will be more tolerant to fragmentation than those with limited dispersal ability (Pearson 1994). For example, barriers to movement between habitats may eliminate juvenile dispersal for many amphibians, potentially leading to demographic instability and local extinction (Gilpin and Soule 1986; Mann, Dorn, and Brandl 1991).

The upland pine savanna and flatwoods communities in which inclusional wetlands occur are also necessary for maintenance of viable amphibian populations, since adults use these habitats. For example, adult pine barrens treefrogs (*Hyla andersonii*) require the arboreal habitat provided in shrub bogs, and the larvae depend on grass-sedge-herb bogs, which have more seepage water at the surface than shrub bogs. Therefore, to maintain viable pine barrens treefrog populations both shrub bogs and adjacent herb bogs must be conserved (Means and Moler 1978). Similarly, flatwoods salamanders breed in ephemeral ponds in savanna and flatwood (Palis 1996). After metamorphosis, post-larval flatwoods salamanders disperse to adjacent flatwoods and sandhills (Palis 1996; Palis and Jensen 1995). Thus, the adjacency of these different habitats in the landscape is of critical importance. Any event that creates barriers between wetland and upland habitats would be detrimental to these species.

Management Recommendations

Type I communities that are chosen to be managed as TES habitat should be connected as much as possible into "Type I management units," which must include any Type III and IV areas within the unit. This can be encouraged by planning

intensive land uses in designated "development zones" (of various types, such as "intensive mechanized training," "low-intensity mechanized training," or "urban development" zones) on the installation. Over time, such landscape-level, long-term land use planning can increase the connectivity of high quality, TES management areas. Reductions in fragmentation support landscape-level management (e.g., prescribed burning) which is more cost-effective. Large areas that are designated as Type I management units may be connected through relatively narrow corridors. Alluvial wetlands and riparian zones may be able to act as corridors, if they provide connectivity between small bogs, seeps, and other depressional wetlands; but corridors may not be effective for all species. Corridors function best if they are short, wide, and free of any gradient that functions as a barrier to wetland species (Pearson 1994). Designation and reliance on corridors requires site-specific research and long-term monitoring.

Changes in Hydrology

Impacts

All of the rare plant species associated with herbaceous seeps and wet savannas are wetland species and will be impacted by changes in hydrology. For example, the Venus flytrap, a Federal species at risk endemic to the Coastal Plain of the Carolinas, is limited to soils having a high water table, an organic hardpan usually not more than 60 cm below the surface, and a pH range of 3.9-4.5 (Roberts and Oosting 1958). This species requires soils that are wet to moist throughout most of the year and cannot survive in areas that become too dry. In addition, it does not typically occur in semi-permanently or permanently flooded sites (Russo et al. 1993). It also requires the high light conditions of open areas. Because of these requirements, the Venus flytrap seldom occurs at locations other than the ecotones of wetlands within sandhill, pine flatwood, and pocosin (Russo et al. 1993). Changes in hydrology, which lead to either drier or more saturated conditions, eliminate habitat for the Venus flytrap and other sensitive species (e.g., rough-leaved loosestrife [*Lysimachia asperulaefolia*], savanna cowbane [*Oxypolis ternata*], pale beaksedge [*Rhynchospora pallida*], Carolina goldenrod [*Solidago pulchra*], and Carolina asphodel [*Tofielda glabra*]; Russo et al. 1993). Changes in hydrology are also particularly harmful to amphibians that use depressional wetlands for breeding and other portions of their life-cycle. Specific activities that impact hydrology in herbaceous seeps and wet savannas are addressed below.

Ditching and draining. Ditching for the purposes of drainage near herbaceous seeps/ wet savannas has had a large negative impact on many of these communities

throughout the Coastal Plain (Bridges and Orzell 1989). Ditches as shallow as 20 cm can cause drying of surface soils in herbaceous seeps and wet savannas (Nixon and Ward 1986). Drainage of these habitats has been widespread, changing species composition and reducing species diversity (Plummer 1963; Eleuterius and Jones 1969). Schnell (1982) studied the combined effects of draining, brush cutting, and burning on a pitcher-plant population in North Carolina, and found that during the first growing season following the treatments, pitcher-plants resprouted from rhizomes and showed increases in growth, probably as a result of reduced competition. Conversely, in the second season, drainage efforts began to dry the soil, and pitcher-plants appeared dried and dead, even though resprouting of shrubs did not appear to be significant enough to provide competition. These results suggest that draining can have a negative effect on the pitcher-plant population, but effects may not be immediate.

Ditching or berming of small, isolated pond-cypress wetlands can result in lowered water levels and shortened hydroperiods (Marois and Ewel 1983). These changes in hydrology could eliminate flatwoods salamander reproduction when shortened periods of inundation lead to egg or larval mortality (e.g., Semlitsch 1983). Altered hydrology, in association with fire exclusion, results in a shift in dominance from pond-cypress to broad-leaved hardwoods, which reduces herbaceous groundcover through shading (Marois and Ewel 1983). This may be detrimental to larval flatwoods salamanders, which use microhabitats having submerged and emergent vegetation (Vickers, Harris, and Swindel 1985; Palis 1995; Palis and Jensen 1995; Palis 1996).

Fire plow lines. Forest management practices often include placement of fire ditches directly through wetlands and wetland ecotones, reducing their water levels as well as suppressing fire in at least part of the habitat (Frost, Walker, and Peet 1986; TNC 1995). Fire ditches running through these habitats also redirect water flow, so that instead of a sheet pattern of flow, water becomes channelized. Similar habitats in Florida have been unintentionally drained by deeply plowed firebreaks that lead away from the site (FNAI and TNC 1995). In North Carolina, fire plowlines have been placed immediately above the slope supporting hillside seeps, altering hydrology and causing drying in the seep (Russo et al. 1993).

Fire lanes plowed through wetlands or adjacent to wetlands have been documented to degrade flatwoods salamander and gopher frog breeding habitat on several military installations. These firebreaks often are placed in the wetland ecotone, and may subsequently alter hydroperiod, provide connections with other wetland systems (which can introduce predatory fish), and/or alter or destroy the herbaceous vegetation at pond margins (TNC 1995). The herbaceous edge of the wetland/upland

ecotone appears to be critical to successful reproduction for the flatwoods salamander, as this zone is often used for egg-deposition. Some firebreaks may hold enough water to make them attractive to amphibians for egg-laying. However, breaks typically dry before the breeding ponds, killing eggs or larvae before they reach metamorphosis (TNC 1995). Fire breaks sometimes cause changes in hydrology, which convert ephemeral pond-cypress depressions into permanent water bodies, rendering them unsuitable for flatwoods salamander reproduction (Palis 1996).

Use of mechanized equipment. The use of mechanized vehicles in herbaceous seeps and wet savannas creates deep ruts that become invaded by more hydrophytic species, and wheel ridges, which become invaded by more xerophytic species (Frost, Walker, and Peet 1986). In addition, wheel ruts in herbaceous seeps and wet savannas may cause channelization of water; the ruts fill with water that previously had been distributed over a larger surrounding area; the surrounding area supporting wetland species becomes dry and will no longer support them (R. Stewart, professional discussion, 11 May 1995; and M. Harper and A. Trame, professional observations, 1995; Figures 6 and 7). Even relatively minor ruts will persist in a wetland community, possibly for decades (M. MacRoberts, Botanist, Bog Research, professional discussion, 24 July 1995 [hereinafter referred to as MacRoberts, 24 July 1995]).

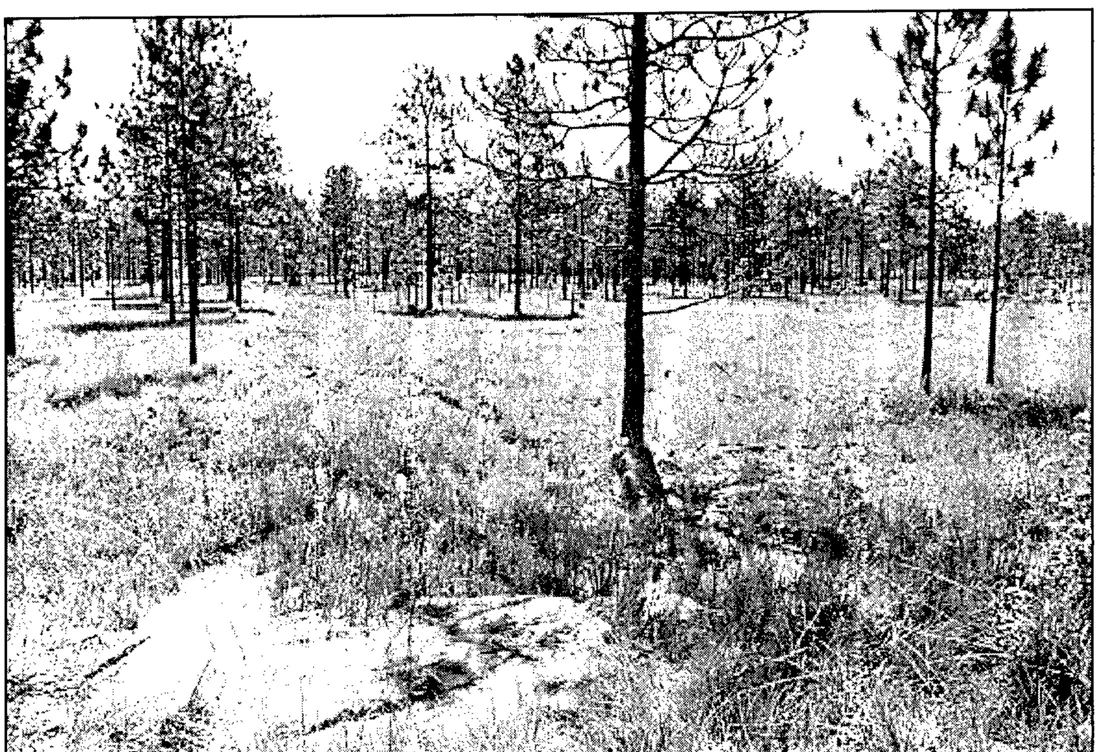

Figure 6. Land immediately adjacent to ruts dries out and can no longer support wetland plants.

Figure 7. The use of heavy machinery in herbaceous seeps and bogs can lead to deep ruts, collecting water that otherwise would move in sheets across the wetland.

Alteration of hydrology can occur on flat areas, gentle slopes, and steeply sloped terrain. In flat areas (such as wet areas that are imbedded in flatwoods), erosion and channeling of water will not occur across very large distances, thus the effect will be localized. However, on steeper terrain associated with hillside seeps or streamhead pocosins, gullies that begin along distant roadways and tank trails on ridge-tops can channel water away from an entire hillside. In these cases, the entire drainage is involved, which poses a landscape-level problem (A. Trame, M. Harper, professional observation).

Mechanized traffic can alter the underlying hardpan layer as well, which would allow the soil to dry out, making it uninhabitable for wetland species (FNAI and TNC 1995). The large tires found on some off-road vehicles may break the organic hardpan that maintains amphibian breeding ponds, shortening the hydroperiod and

rendering the pond unsuitable for amphibian reproduction (Palis 1995). Long-term tank maneuvers can lead to conversion of an herb bog community as early successional, upland species, such as wax myrtle and St. John's-wort, invade the drier soil (Figure 8). Once this occurs, frequent fires will not be adequate to restore the community (FNAI 1994a). The lowest-lying areas can pond water, creating habitat for marsh species such as button bush, cattails (*Typha latifolia*), and marsh panic grasses (*Panicum* spp.; A. Trame, professional observation). After moderate to high levels of tank training, the community may become so degraded that restoration becomes impossible or prohibitively expensive (MacRoberts, 24 July 1995). Thus, it is likely that healthy inclusional wetland communities and mechanized vehicle traffic are incompatible in the southeastern U.S. (LeBlond, Fussell, and Braswell 1994c).

Siltation in herbaceous seeps and wet savannas. Siltation into a wetland community can smother bog species and alter hydrology (Figure 9). Siltation can result from erosion in upland sandhill communities that follows heavy soil disturbance activities. Sedimentation can alter natural aeration, nutrient, and water conditions (Russo et al. 1993). Deep deposits of sand can smother understory plants and even kill overstory trees. Species that normally do not occur in wetland

Figure 8. This former bog was drained by tank ruts and is now dominated by wax myrtle and St. John's-wort; deep ruts remain under the vegetation.

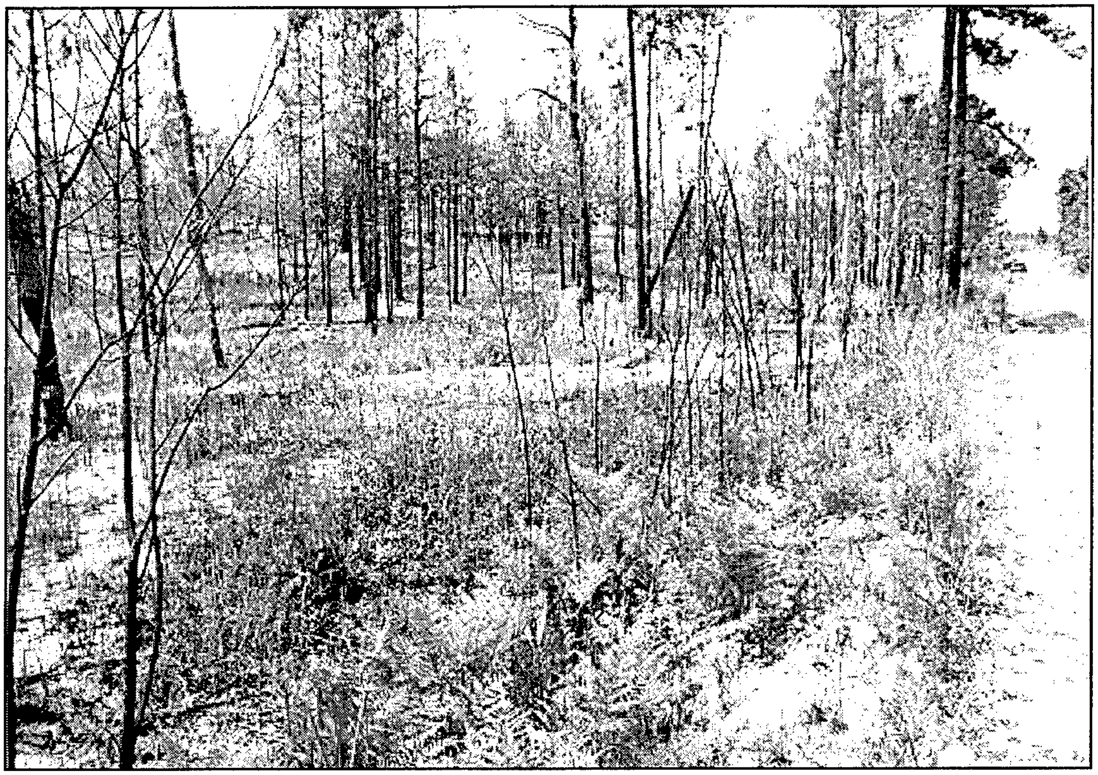

Figure 9. Siltation of a high quality seepage bog due to a nearby road.

environments may have a competitive advantage in the new sandy substrate (Russo et al. 1993). The relationship between mechanized vehicles and siltation into inclusional wetland communities is undocumented. However, sedimentation is potentially a serious threat and should be frequently monitored in any wetland community that harbors TES.

Compaction. Compaction can result from mechanized vehicle use or other activities. Although wetland soils are susceptible to compaction, they may also have some potential for recovery if they experience wet/dry cycles and/or swelling and shrinking due to high clay content. More research is needed in this area, since there are likely to be many site-specific influences on compaction and recovery. Compaction can be a serious impact, since lateral subsurface flow is important in wetland sites. In the flatwoods of the Francis Marion National Forest, compaction from skid trails reduced lateral groundwater flow and dried one side of the study site (Aust et al. 1993). Such alterations would probably affect community composition and be detrimental to rare species that are sensitive to changes in soil moisture.

Fire suppression. Woody species invade herbaceous seeps and wet savannas in the absence of fire. Fire suppression over a 20-year period resulted in the elimination

of the herbaceous seep/wet savanna ecosystem (Folkerts 1982) in some Gulf Coast areas.

Fire suppression adjacent to shrub bogs can reduce groundwater seepage entering from upslope, for similar reasons. In addition, long-term fire suppression that leads to hardwood dominance of a pine savanna or small depression pond can decrease infiltration. Infiltration of rainfall reaching the ground surface of deep, sandy soils can be 100 percent, even when vegetation cover is sparse. When dominant vegetation shifts from pines and herbaceous groundcover to hardwoods, the water entering subsurface soils decreases (Platt et al. 1990).

Adjacent land uses. Clearcutting pine adjacent to herbaceous seeps and wet savannas will increase groundwater seepage. However, the dense stands of planted pines that develop after clearcutting will dry the wetland community (Means and Moler 1978). Adjacent land uses such as clearcutting can compact soil and cause decreased transpiration. This increases runoff and decreases groundwater flow, and may lead to cycles of inundation and drought, rather than consistent, slow release of water from groundwater sources (Pearson 1994).

Management Recommendations

Watershed boundaries and buffer zones. If landscape-level conservation of inclusional wetlands for TES is a land management goal, then two rules should be applied: (1) target land management and monitoring to maintain quality wetlands, stream courses, ponds and lakes, and (2) mitigate erosion and sedimentation problems quickly. If wetlands and waterways are high quality, the ecological status of uplands and terrestrial systems is probably acceptable as well. This does not suggest that managers should not monitor terrestrial sites, but that wetlands and streams can serve as critical indicators for overall ecosystem status. Erosion damage should be repaired before it becomes a major obstacle to training or threatens Type I or Type II natural areas. This will be more cost-effective and sustainable in the long-term.

Activities that can alter hydrology in Type I or Type II herbaceous seeps/wet savannas and small depression pond complexes should be allowed only if it is determined that such alterations will benefit the community. Some enhancement of seepage may be desirable in areas that have become dominated by woody growth due to fire suppression (Platt et al. 1990).

Watershed boundaries should be defined so that an adequate buffer zone protects the watershed. In general, water that maintains hillside seeps must come from

positions topographically higher than the seep itself (Platt et al. 1990). The area extending to the top of the hill should be protected as the potential watershed, as well as the area extending to the drain below the seep. On broad, shallow slopes, it may be difficult to precisely determine the recharge area. In these cases, an outer buffer should extend to at least 60 m beyond the edge of the active seeps. Vegetation patterns can often be used to identify wetland boundaries. Alternately, soil moisture can be examined to determine whether or not a seep is active (Platt et al. 1990). This latter approach is most effective in late winter/early spring, when water flow is greatest, or after fires have removed woody vegetation and litter.

In any case, a buffer surrounding the community should also be protected. The general rule is to protect a buffer that extends 30 m in all directions from the edge of the active seep (Platt et al. 1990). However, recommendations for buffers vary. For example, the recovery plan for rough-leaved loosestrife states that although the minimum buffer should be 30 m, a boundary extending 60 m is preferred (USFWS 1995). Palis and Jensen (1995) suggested prohibiting vehicular use (except for emergency and natural resource enhancement) within 50 m of upland wetland depressions, particularly gopher frog breeding sites. They also suggested that roads passing near or through wetlands be closed or rerouted (Palis and Jensen 1995). Given the current lack of agreement on buffer size, further studies are needed to determine the boundary necessary for protection. In the meantime, managers can monitor the effects of activities occurring outside of designated buffer zones to determine if a larger land area should be protected.

Ditching and draining, fire plow lines. Type I or Type II herbaceous seeps, wet savannas, and small depressional ponds that are valued as TES habitat or for watershed management, and their buffer zones, should not be compromised through ditching and draining, nor through the installation of fire plow lines in the wetland or its upland ecotone, as this will destroy such communities. The natural hydrology of aquatic habitats should be restored on sites where TES habitat is desired (by removing berms, filling drainage ditches, and/or adding road culverts) but this is much more difficult than preventing the damage initially. If wetland protection is desired, mechanical disturbance of the wetland-upland ecotone should be avoided, and the practice of "protecting" wetlands by encircling them with plow lines should be abandoned.

Use of mechanized vehicles. Activities that create deep ruts through herbaceous seeps and wet savannas and/or their surrounding buffer zones can negatively alter hydrology; therefore, within wetlands and buffer zones, such activities should be avoided. Heavy machinery should never be used within the herbaceous seep/wet savanna itself. If heavy machinery must be used in the buffer zone (e.g., for timber

removal), only skidders with large, soft tires should be used, and use should only occur during the driest weather, to minimize rutting and compaction.

Timber removal. Removal of trees from fire-suppressed Type II or Type III seeps may be necessary when trees have shaded out herbaceous vegetation. Within seeps, trees should be removed preferably by hand-cutting, or alternatively by careful use of approved stem-selective herbicides. Scattered longleaf pines are characteristic of these communities, so a few older trees should be left (Platt et al. 1990). Broadcast application of herbicides within herbaceous seeps and bogs and/or their adjacent buffer zones is not recommended under any circumstances. The effect of herbicide or fertilization application is a concern in these wetland communities and these substances have been implicated in amphibian declines. Fertilization may result in eutrophication of wetlands, promoting undesirable algal blooms.

Removal of timber in the zone upslope from a seep can be used to restore natural seepage patterns in Type II habitats. Timber removal activities may be needed to maintain a low stocking rate of longleaf pine. Platt et al. (1990) recommend establishing and maintaining a stocking rate of 9.2 to 13.8 square meters per hectare (40 to 60 square feet per acre) in the zone upslope from a seep. There is much variability in this figure, due to the variation observed in natural communities (L. Smith, Ecologist, Louisiana Natural Heritage Program, professional discussion, 7 June 1996 [hereinafter referred to as "L. Smith, 7 June 1996"]). In the seep/wet savanna itself, a much lower basal area would be expected. Measurements of basal area in habitats that support healthy rough-leaved loosestrife populations suggest that the basal area in adequate habitat ranges from 4.6 to 9.2 m^2/ha (20 to 40 sq ft/acre; Directorate of Public Works and Environment 1996). Sensitive, noninvasive practices, such as those used in streamside management zones (e.g., directional tree falling) should be used near herbaceous seeps and wet savannas.

In functioning wetlands (Type I and most Type II areas) prescribed fire should adequately control woody encroachment. However, if prescribed fire is not effective in restoring the desired open conditions, timber removal should be used to maintain ground cover integrity.

Changes in Fire Regime

Impacts

Fire is considered by some to be the most important factor necessary for the maintenance of herbaceous seep/wet savanna communities, because regardless of

other factors, the absence of fire leads to the elimination of light-demanding wetland species (Folkerts 1982; Nixon and Ward 1986). Suppression of fire in these habitats has caused wide-scale changes. Communities that were not intentionally converted for agricultural or other purposes have often been destroyed by fire suppression. In the absence of fire, pine woodlands and the associated herbaceous seeps and wet savannas have succeeded to the loblolly pine stands and bottomland hardwood habitats observed in most areas today (Frost, Walker, and Peet 1986).

Frequent fires have been observed to maintain high species diversity in herbaceous seeps and wet savannas (Eleuterius and Jones 1969; Figure 10) and allow for more successful reproduction of native plants (Barker and Williamson 1988; Eleuteris and Jones 1969). In longleaf pine depressions, there are over 100 species of herbs, many of which are lost within a few years of fire exclusion (Nixon and Ward 1986).

Woody species are quick to invade wetland areas when fire is suppressed. For example, areas of wetland habitat in Alabama were encroached by shrubs and loblolly and slash pine when fire frequency was reduced from 1 to 3 years to every 5 years (Frost, Walker, and Peet 1986). In addition, fire exclusion for as little as 3 to 5 years may lead to deep litter accumulation, preventing seedling establishment in pitcher-plants and other species that require bare mineral soil for germination and seedling growth. Fire suppression also reduces flowering in pitcher-plants, such that most individuals in a stand eventually fail to flower at all (Folkerts 1990; Nixon and Ward 1986).

Figure 10. Frequent fires caused by artillery fire have maintained this high quality bog.

Compositional changes affect the fauna of the ecosystem as well as directly altering the plant community. For example, flatwoods salamander breeding sites that have been fire suppressed may become overgrown with Chapman's St. John's-wort (*Hypericum chapmanii*). The subcanopy formed by dense stands of this plant may reduce herbaceous groundcover, thereby eliminating breeding microhabitat (Palis and Jensen 1995).

When fire is reintroduced and woody vegetation is cleared, plants that have remained dormant in the soil may reappear. For example, the rhizomes of white-topped pitcher-plant (*Sarracenia leucophylla*) are very long lived and capable of surviving in the dormant state for decades without producing pitchers or flowers. At a site that was planted in pines in the early 1960's, the pitcher-plants disappeared during the 1970's and early to mid 1980's, then reappeared after the pines were harvested (Folkerts 1990).

Management Recommendations

Prescribed burning. Few studies have specifically examined the effects of fire frequency and season on shrub and hardwood invasion in these wetland habitats (e.g., Olson and Platt 1995), and even fewer have produced unequivocal results. Despite a lack of rigorous empirical evidence to support suggestions for season and frequency of managed burns, the most rational recommendation would prescribe a fire regime that simulates the natural occurrence of fire in these communities. Given that natural fires in upland communities are most frequent during the spring, presumably, wetland inclusions also burn at this time (Komarek 1964; Chen and Gerber 1990). Yet, historical and contemporary land managers have typically burned sites during the winter when fires are most easily controlled and previously believed to be least harmful to pines (Frost, Walker, and Peet 1986; Streng, Glitzenstein, and Platt 1993).

Growing season burns have been found to significantly reduce the above-ground biomass of certain shrub species in wet savannas, whereas late summer burns do not (Olson and Platt 1995). Furthermore, seasonal effects of prescribed burns are potentially important in determining ground cover diversity (Streng, Glitzenstein, and Platt 1993; Glitzenstein et al. unpublished manuscript). Because many native species are dependent upon spring/summer burns for flowering and fruiting, the season of fire may affect species composition over the long term by controlling which species become established in the disturbance patches made available by fires (Streng, Glitzenstein, and Platt 1993; Glitzenstein et al. unpublished manuscript). Therefore, restoration and maintenance efforts should include early growing season fires to ensure establishment of naturally occurring wetland species. For example,

Platt et al. (1990) recommended that burns occur between 1 April and 30 June at a site in the Kisatchie National Forest, LA. For flatwoods salamander and gopher frog conservation, fires will need to be implemented during the growing season so that they burn through the dry or nearly dry depression ponds, thereby maintaining the grassy wetland margin (Huffman and Blanchard 1990).

Annual fires are important for preventing hardwood dominance in upland pine savanna and flatwood communities where shrubs and hardwoods have already become established—which is the most prevalent condition given wide-spread fire suppression throughout the Southeast (Streng, Glitzenstein, and Platt 1993; Glitzenstein et al. unpublished manuscript). But in areas where shrubs have not yet become established, less frequent burns (about 1 to 3 years) are probably adequate for maintaining community integrity (W. J. Platt, Plant Population Ecologist, Department of Biological Sciences, Louisiana State University, professional discussion, October 1997). If fire frequency is assumed to have a similar effect on wetland communities, then a comparable management strategy should be adopted. For sites where fires have been suppressed, an initial fuel reduction burn during the dormant season may be necessary. Thereafter, yearly spring burns will keep woody species under control. After this period (when high fuel loads are an issue) burn frequency should vary from 1 to 3 years, and the time of burn should also vary (between 1 April and 30 June; see Harper et al. 1997). Burns occurring during the dormant season are more likely to kill rare amphibians than burns during the growing season. If winter burns are needed, they are best conducted before salamanders begin migrating to breeding ponds (i.e., before October; Means 1972; TNC 1995). Modest amphibian mortality associated with winter burning may be outweighed by the benefits of reintroducing fire to the wetland ecosystem (John Palis, Biological Consultant, Jonesboro, IL, professional discussion, 13 August 1996). However, it is recommended that the Fish and Wildlife Service be consulted on such decisions, and that any affected population be carefully monitored to evaluate the effect of such a decision.

Fire prevention. Firebreaks should not be established in herbaceous seeps, wet savannas, or their ecotones, and should be established only in the outer buffer boundary when controlling fire is necessary, and less destructive means of controlling fire are deemed inappropriate. Fire plowlines already in existence that alter the hydrology in herbaceous seeps and wet savannas can be filled in using indigenous soil and allowed to revegetate. Firebreaks in general should be allowed to revegetate so that important wetland sites burn along with the surrounding upland community (FNAI and TNC 1995). If new fire plowlines must be developed in an emergency situation to control a fire, mowing instead of plowing may be a less destructive method (M. Davis, June 1997). Plowed firebreaks should be restored

immediately, using native vegetation (Department of the Air Force 1993) and indigenous soil (LeBlond, Fussell, and Braswell 1994a), if TES or Clean Water Act considerations warrant the maintenance of natural hydrologic conditions. Abandoned plowlines may also be rehabilitated in the same way (LeBlond, Fussell, and Braswell 1994a) when natural revegetation seems unlikely. Managers are encouraged to use streams and other natural firebreaks to control fire whenever feasible.

Exotics or Pest Species

Impacts

Feral hogs (*Sus scrofa*) pose a severe threat to wetlands. Hog rooting kills plants directly, increases soil erosion, and facilitates weedy species invasion (Figure 11). Hog activity can degrade habitats so severely that they are no longer able to support native ground cover and rare species. For example, one wet prairie noted as high quality during a survey was severely damaged by hogs only months later (FNAI 1994b).

Figure 11. Feral hogs trample wetland plants, increase the potential for soil erosion, and facilitate weedy invasions of herbaceous seeps and wet savannas.

Some people consider beavers to be pests, because they can damage trees. In addition, at Fort A. P. Hill, VA, biologists have determined that the most serious threat to swamp pink (*Helonias bullata*) is destruction of seepage swamp habitats by beaver impoundments and flooding (Fleming and Van Alstine 1994). Fleming and Van Alstine (1994) recommend monitoring beaver activities in watersheds that support swamp pink. On the other hand, beaver impoundments produce wetland habitat that may support a variety of wetland species.

Activities that disturb soil or alter hydrology, especially bulldozing of roads and fire lanes, increase susceptibility of communities to invasion by species not natural to the community. Old field weeds may invade following disturbances; this may reduce fire frequency and facilitate hardwood invasion (Abrahamson and Hartnett 1990). Often, problem species in herbaceous seeps and wet savannas are off-site species that have invaded the site after fire suppression. Chinese tallow (*Sapium sebiferum*) is already a major concern in Texas and Louisiana wetlands and is expected to become more widespread (G. Tanner, Associate Professor, University of Florida, professional discussion, August 1996). Activities that may increase susceptibility of herbaceous seeps and wet savannas to invasion by exotic species are listed in Table 6.

Table 6. Activities that may lead to invasion by species that are not native to the community.

Activity	Effects
Hog rooting	Destroys vegetation and churns up soil, freeing resources for the establishment of exotics. Feral hogs may also be responsible for transporting non-native propagules into the community.
Cattle grazing	Cattle grazing and trampling in herbaceous seeps and wet savannas can favor rhizomatous, grazing-tolerant grasses at the expense of natives. Cattle also can nutrify the area, and this may affect species composition (L. Smith, 7 June 1996).
Adding fill dirt	May add nutrient-rich soil into a nutrient-poor community. Propagules of invasive plants can be transported in the fill.
Fire suppression	Changes physiognomic structure of community, reducing the rigor of natives and freeing resources for non-natives.
Fire plowlines	Suppress fire and create open spaces, freeing resources for non-natives. Establishment of fire plowlines through small depression ponds may lead to connections with other wetland systems, which will allow for the introduction of foreign fauna. This can pose problems, especially if predaceous fish are introduced (TNC 1995).
Erosion control projects	Introduction and encouragement of non-native, erosion control species.
Use of ORVs	Can destroy native vegetation, thus freeing resources for non-natives. Exotic propagules can be brought into the community on tires of vehicles.
Fragmentation	Creates more edge habitat in natural communities, and edges tend to be more easily invaded than interior habitats. Also creates more land adjacent to natural communities that supports populations of species that may be detrimental.

Management Recommendations

The presence of exotic species disrupts the natural processes of high quality (Type I or Type II) communities. Control efforts should emphasize preventing the conditions that allow establishment of nonnative species. The following paragraphs discuss important considerations.

Feral hogs. Hogs should be trapped and hunted. Daily bag limits on hunting hogs should be discontinued and hog hunting should be allowed whenever other game seasons occur. When hunting is not allowed, hogs should be trapped. Hog populations should be monitored to asses progress in control efforts (FNAI 1994a).

Beaver impoundments. Biologists at Fort Bragg, NC, have recommended that beaver impoundments be maintained, because they support rare bog species. Beaver eradication is discouraged, except when absolutely necessary (Russo et al. 1993). Control of beavers should be determined by the management goals of individual sites.

Exotic plants. Managers can obtain a copy of Langeland (1990), *Exotic Woody Plant Control* for information regarding control of exotics. To do so, contact C. M. Hinton, Publications Distribution Center, IFAS Building 664, University of Florida, Gainesville, FL 32611.

Careful manual removal of exotic species is the preferred removal technique in high quality TES habitat, if effective. However, it appears that manual removal in herbaceous seeps and wet savannas may not always work; unless the entire stem is removed, plants may resprout. Removal of entire stems in wetland areas is likely to disturb soils and hydrology. Therefore, using stem-selective herbicides rated for wetlands may be the most practical method of removal (L. Smith, 7 June 1996). Herbicides must be safe for use in wetlands, and managers should monitor herbicide effects on plants and wildlife. Mechanical removal (using bulldozers or specialized logging equipment) should never be used in wetland areas, because it causes severe disturbance to soils, hydrology, and nontarget vegetation (Langeland 1990).

Herbicides have been used with success to remove woody exotics. Herbicides should never be broadcast within or immediately adjacent to rare species or any permanent or seasonal wetlands. Indiscriminant herbicide application can affect water quality and present a direct threat to rare species (Russo et al. 1993, USFWS 1983).

If herbicides must be applied, methods and timing should minimize effects on nontarget vegetation and the environment. The herbicide applicator must be well

informed of the chemical properties of the herbicide, and under what circumstances it should be applied. Environmental precautions are stated on the herbicide label. In general, these guidelines should be followed:

- Only the minimum recommended amount should be used (Department of the Air Force 1993).

- Herbicides should never be applied aerially in natural areas. Application techniques such as spot treatments that ensure the herbicide only contacts target plants, should be used.

The applicator should be aware of potential weather conditions and should schedule applications accordingly (Langeland 1990).

- Heavy rainfall following application may result in damage to nontarget vegetation. Drought conditions preceding application can affect herbicide efficacy, because drought-stressed plants are less likely to absorb herbicides.

- Excessive wind may result in poor coverage to the target vegetation and cause drift that results in damage to nontarget vegetation. Excessive wind can indirectly affect the ability of the plant leaves to absorb herbicides.

- In low temperatures, plant growth slows down, and this may decrease herbicide absorption or activity.

Fertilization

Impacts

Fertilizer affecting herbaceous seeps and wet savannas can originate in adjacent lands that are used for agriculture or plantations. At least one Army installation has received proposals suggesting that treated sewage sludge be applied to intact wooded areas (Russo et al. 1993). Such alteration of the nutrient cycle is disruptive to the community and is expected to reduce a site's suitability for TES plant species.

Carnivorous plants characteristic of many herbaceous seeps and wet savannas are adapted to nutrient-poor communities with acid soils (Folkerts 1977), and fertilization activities would be expected to eliminate these species by changing soil-nutrient conditions and allowing more competitive species to invade. In one study, Eleuterius and Jones (1969) applied fertilizer and found that productivity of pitcher-

plants (*Sarracenia alata*) declined. In another study, Walker and Peet (1983) found that fertilization in annually burned mesic savannas doubled peak standing crop the following summer, but no further increase was observed after four seasons of fertilization. Fertilization in mesic savannas resulted in no decrease in species during the first year, and after 4 years, the drop in richness was no more than in the control plot. Walker and Peet (1983) did not conduct fertilization experiments in wet savannas, which are most similar to the herbaceous seeps and wet savannas discussed here.

Management Recommendations

Fertilization activities should be avoided within herbaceous seeps and wet savannas, small depression pond complexes, and surrounding buffer zones.

Disturbances to Vegetation and Soils

Impacts

Herbaceous seeps and wet savannas have soft soils and bog species are fragile. Therefore, soil disturbance events in these communities are extremely disruptive. Soil disturbance can be caused by activities such as trampling, grazing, feral hog rooting, and vehicle use. Disturbances in upland communities also can lead to erosion and deposition of silt in lower-lying communities, raising the soil surface and directly affecting plants in the lower-lying community (Brown, Stone, and Carlisle 1990). Little is known about the effects of soil disturbance on hundreds of wetlands species (Frost, Walker, and Peet 1986). Soil disturbances that alter the hydrology are expected to have the greatest effect on plant populations in wet communities. Conversely, disturbances that only damage individual plants should have a lesser effect on the plant populations.

Low intensity, nonmechanized activities, such as troop movements on foot, are not known to have significant positive or negative impacts. As a general rule, activities that affect only aboveground growing parts of plants should not be detrimental to rare species populations. This is because most plants in herbaceous seeps and wet savannas are fire-adapted perennials. Adaptations include: well-protected underground perennating structures, meristems protected near the ground by insulating tissues, fire-induced flowering and seed production, and basal sprouting capabilities. Activities that uproot several plants or disturb the soil will cause declines in population sizes of some species. More robust forms may exhibit greater tolerance for soil disturbing activities. Species that have a geographically narrow

range are at most risk from soil disturbances, because a single action could negatively impact a large portion of the population (Walker 1993).

Hybridization of pitcher-plants can result from physical disturbance. This may occur because disturbance moves propagules and creates sites for colonization. Compared to nonhybrids, pitcher-plant hybrids require more water, are more sensitive to water stress, have less viable shapes, and appear to have dysfunctional metabolic pathways. Hybrids may have lower pollination success than nonhybrids. In fire-suppressed areas, hybrids appear to be less competitive than nonhybrids when competing with woody invaders for resources (reviewed in Folkerts 1982).

Losses in vegetation impact the fauna of wetland ecosystems. Means, Palis, and Baggett (1994) suggested that local flatwoods salamander populations may be extirpated from areas that lose excessive amounts of native terrestrial groundcover. These losses may stem from mechanical site-preparation of the soil, herbicide application, fire suppression, rutting and soil-compaction resulting from timber harvests during wet periods, or a combination of these impacts (Palis and Jensen 1995).

Cutting. One study (Schnell 1982) found that cutting and chopping that did not uproot herbaceous plants, but cut them to nearly ground level, appeared to have a positive effect on pitcher-plant populations. However, the control was poor since it was a long-unburned site. In addition, the area was ditched and drained, and the pitcher-plant populations declined in the second growing season after treatment, possibly due to the delayed effects of draining. Therefore, longer term studies that have high-quality controls, and are designed to test for individual treatment effects are still needed (Folkerts 1982).

Vehicle Use. A healthy, natural bog community cannot sustain any vehicle disturbance at all, regardless of time of year (LeBlond, Fussell, and Braswell 1994c). Ruts formed by vehicles will pool water, and can support more hydrophytic species than naturally would occur; the wheel ridges are drier than normal, so they provide sites for invasion by more xerophytic species (Frost, Walker, and Peet 1986). Even one pass of a heavy tank will create deep enough rutting to divert the natural overland water flow into a narrow channel, drying out the surrounding areas (R. Stewart, 9 May 1995; A. Trame, M. Harper, professional observation; Figure 8). At Eglin AFB, FL, recreational ORVs are highly destructive to vegetation in sensitive wetland habitats. This is due to both mechanical disturbance and hydrologic alterations due to rutting and soil compaction (FNAI 1994a). ORV use also has threatened the integrity of flatwoods salamander breeding sites (Palis and Jensen 1995). Gopher frog breeding sites also are often degraded by ORV use or by sand

roads that pass through or adjacent to the ponds (Palis 1995). Vehicle traffic disrupts pond floor micro-topography and eliminates herbaceous vegetation (Palis 1995). Loss of herbaceous vegetation from ORV use could also discourage gopher frog reproduction, since egg masses are attached to stems of herbaceous vegetation (Bailey 1990; Palis 1995). Erosion of unpaved roads lying adjacent to breeding sites may result in an influx of sedimentation from surrounding uplands during rainstorms. Introduction of sediment is exacerbated by emplacement of wing ditches that divert water from roads into ponds (Palis 1995).

Grazing and trampling. Ungulates are believed to selectively remove protein-rich forbs and favor disturbance-tolerant species (Frost, Walker, and Peet 1986). In a wet savanna in Louisiana, grazing by cows has favored the rhizomatous carpet grass (*Axonopus affinis*) over species typical of the community (L. Smith, 7 June 1996). However, experience suggests that cattle seldom feed on carnivorous plants in herbaceous seeps and wet savannas. Thus, it has been suggested that unimproved pasturing may not be detrimental to these carnivorous plants (but intensive pasturing, involving discing and planting of forage plants, will eliminate carnivorous plants; Folkerts 1977). Although cattle may not feed on individual plants, trampling is likely to interrupt hydrology in bogs and affect plant species. In addition, plants in herbaceous seeps and wet savannas are adapted to nutrient-poor conditions, and cattle are likely to nutrify the community (L. Smith, 7 June 1996).

The damage to ground cover and other plant species by military foot traffic and occupation activities may be comparable to that caused by recreational activities such as hiking and camping. Most available information comes from recreational studies outside the southeastern region. In these studies, trampling injury to plants by recreationists caused damage similar to nutritional or disease stress, and included abnormal cellular activity and impaired root formation, photosynthesis, respiration, and energy metabolism (reviewed in Kuss and Graefe 1985). A reduction in growth, vigor, and reproduction are common impacts (Kuss and Graefe 1985; Cole 1987).

Management Recommendations

Inclusional wetlands and high quality sites (including all Type I, Type II, and TES sites) should be protected from negative impacts such as erosion, sedimentation, compaction, fire suppression, and intensive trampling or ground disturbance. These sites should not be used for any mechanized training, including occupation scenarios that involve vehicles (Russo et al. 1993; LeBlond, Fussell and Braswell 1994a). A buffer zone of protection should extend well across ecotones to prevent sedimentation into wetlands, fire suppression due to loss of fuels, or changes to hydrology of

wetlands and uplands. A buffer of at least 60 m on slightly sloping lands or 30.5 m on flat terrain is recommended. For hillside seeps or streamhead pocosins in hilly areas, the immediate drainage should be protected from the top of the slope to the drain below the bog, since recharge and discharge patterns are critical for wetland conservation. Traffic on nearby dirt roads or trails in adjacent areas should be minimized; if traffic does occur, the road should be monitored carefully for erosion (Jordan, Wheaton, and Weiher 1995).

Vehicle use. Military vehicle operators can be trained to recognize and avoid hillside seeps and wet savannas by teaching them to recognize pitcher-plants and sedges. Any high-quality seep or savanna that managers wish to maintain in such a state should be closed to all vehicular traffic.

The same recommendations are made with regard to forestry operations. "In no case should machinery enter the bog itself. [In the buffer zone], timber removal should be conducted in a manner that favors the maintenance of indigenous ground cover vegetation and minimizes soil disruption: use only skidders with large, soft tires, log only in driest weather to prevent rutting and compaction, do not drag log butts or ends on the ground, do not damage trees to remain on site, designate log-haul routes if this will minimize overall soil/vegetation disruption, leave no logging slash piles, locate log landing areas outside of registered natural areas. Mechanical site preparation activities, such as drum-chopping or discing, should never be conducted in these areas...The continued practice of timbering in the buffer zone is contingent upon the activity not causing significant soil disturbance and damage to the herbaceous layer. The effects of logging on ground cover must be assessed after each logging event. If it is determined that there has been significant disruption of the soil and herb layer, as judged by the presence of [weedy species]...and by the reduction or elimination of certain disturbance-intolerant species...timber management in the buffer zone must be appropriately modified" (Platt et al. 1990).

Grazing and trampling. If cattle grazing or trampling is shown to be disruptive to a herbaceous seep/wet savanna, steps should be taken to attract cattle away from the community. Fencing may be necessary as a last resort. Low intensity foot traffic can be tolerated by Type I seeps or bogs (Trame and Harper 1997), while moderate levels are acceptable in Type II or III communities.

Restoration Activities

The following recommendations are made for restoration of lower quality areas (e.g., Type II areas that managers wish to be elevated to Type I status) to provide

additional TES habitat in locations that (1) increase connectivity of TES habitat, or (2) minimize potential conflict between military training activities and TES requirements.

1. Reduce stocking of pine in areas that have been converted to woodland, to restore hydrology and open conditions required by native species.

2. Fill in ditches that alter hydrology with indigenous soil, and allow to revegetate naturally, or restore the native groundcover.

3. Implement a growing season prescribed fire regime. Winter fires may be implemented initially, if it is determined beforehand that there are no rare amphibian populations to be affected. If burning is not feasible, methods that do not disturb the soil should be used to remove woody species.

4. Convert sites from loblolly or slash pine to longleaf pine, within the range of longleaf. This should be conducted in such a way that an uneven-aged stand is maintained.

5. Restore the groundcover. There is little information on restoration of groundcover in herbaceous seeps and wet savannas (for restoration of wiregrass, see Harper et al. 1997). Rhonda Stewart (11 May 1995) has been successful at restoring bog species by removing plugs (e.g., 30 cm in diameter) from healthy areas and transplanting them into degraded areas. The bog species grow outward from the plug and soon dominate the groundcover.

6. Continue to monitor progress of restoration activities, and modify management according to results of monitoring.

6 Summary and Conclusions

Inclusional wetland communities, including herbaceous seeps, wet savannas, and Coastal Plain depression pond complexes, are characterized by sensitive hydrologic regimes, diverse floras and faunas, and ecological processes closely linked to those of the surrounding landscape. Herbaceous seeps and wet savannas are ecosystems dominated by grasses, sedges, and composites with an absence of a shrub layer or a tree canopy (although scattered trees or shrubs may occur). They are characterized by frequent fire, acidic soils, seasonal flooding or frequent saturation, and the occurrence of carnivorous plants. Coastal Plain depression pond complexes are complexes of small, isolated, seasonally or permanently flooded depressions found in pinelands. All of these communities have similar hydrologic properties, and provide important breeding sites for amphibians. These wetland communities are important habitat for dozens of plant and animal species on at least 21 DoD installations in the Southeast.

The ecological integrity of inclusional wetland communities is controlled by topography, soil characteristics, and hydrology. All are maintained when groundwater is discharged or when surfacewater is restricted in its downward flow. Some of these communities experience seasonal drying, while others are constantly saturated or inundated. Despite hydrologic variation among communities and across the region, species adapted to these habitats will depend greatly upon maintenance of the characteristic hydrologic pattern of a particular site. Several activities can alter hydrologic patterns and negatively impact the plants and amphibians associated with inclusional wetlands. Intentional ditching and draining creates an obvious impact, but other activities can lead to "accidental" draining of a wetland. Plowing of fire breaks is widely recognized as a detrimental practice. Fire lines can redirect water flow, change hydroperiod, connect isolated wetlands to other water bodies, and destroy pond vegetation. The use of heavy equipment creates deep ruts that disrupt water flow or leads to gully erosion that can drain an entire hillside. Similarly, nearby soil disturbances may lead to soil deposition and filling of wetlands, smothering vegetation, creating new soil substrate, and drying the surface of the site. The only management strategy available for preventing impacts is to avoid damaging activities in any wetland that provides TES habitat or is valued for other ecological qualities. It is critical to delineate the necessary buffer distance around herbaceous seeps, wet savannas, and depressional ponds, but there

is little data available to guide this decision. Identification of appropriate buffer distances for different soil types and on different terrain warrants careful attention, exchange of lessons learned, and applied research efforts.

While topology, soils, and water flow provide many of the physical conditions needed by wetland plants, fire frequency and intensity provide a competitive edge to the light-demanding herbaceous species that dominate these southeastern communities. Herbaceous seeps and wet savannas require frequent fire to prevent invasion and dominance by certain woody species. Fire may also be important in maintaining depression pond communities; it restricts the development of peat as well as the invasion of shrubs and trees. TES habitat sites will benefit from frequent fires, which is one reason why high-quality habitat is often found in and near the explosives impact zones on southeastern DoD installations.

Planning for fire management in inclusional wetlands should consider the desired fire regime of surrounding upland communities, since adjacent sites have been affected by large-scale burns for hundreds of years. Many areas that have experienced fire suppression will require intense annual burns to restore high-quality wetland and upland communities. However, a fire frequency of 1 to 3 years is adequate for sites without shrub invasion. Historically, the southeastern ecosystems burned most often in the spring or early summer, when shrub species may be most vulnerable to fire-related mortality. This may be the best time to burn depression pond complexes as well, since they will likely be dry. However, any prescribed fire plan should include variation in burn schedules (both in terms of burn intervals and burn season) to maintain a diversity of species.

Herbaceous seeps and wet savannas have soft soils and bog species are fragile. Therefore, soil disturbance events in these communities are extremely disruptive. Soil disturbance can be caused by activities such as trampling, grazing, feral hog rooting, and vehicle use. Little is known about the effects of soil disturbance on hundreds of wetland species. Soil disturbances that alter hydrology are expected to have the greatest effect on plant populations in this community. Conversely, disturbances that damage only individual plants should have a lesser effect on the plant populations.

Losses in vegetation affect the fauna of wetland ecosystems. For example, local flatwoods salamander populations may be extirpated from areas that lose excessive amounts of native terrestrial groundcover. These losses may stem from mechanical site-preparation of the soil, herbicide application, fire suppression, rutting and soil-compaction resulting from timber harvests during wet periods, or a combination of these impacts.

Inclusional wetlands that are valued as high quality TES habitat should be protected from negative impacts such as erosion, sedimentation, compaction, fire suppression, and intensive trampling or ground disturbance. These areas should not be used for any mechanized training, including occupation scenarios that involve vehicles. A buffer zone of protection should extend well across ecotones to prevent sedimentation into wetlands, fire suppression due to loss of fuels, or changes to hydrology of wetlands and uplands. A buffer of at least 60 m on slightly sloping lands or 30.5 m on flat terrain is recommended. For hillside seeps or streamhead pocosins in hilly areas, the immediate drainage should be protected from the top of the slope to the drain below the bog, since recharge and discharge patterns are critical for wetland conservation. Traffic on nearby dirt roads or trails in adjacent areas should be minimized; if traffic does occur, the road should be monitored carefully for erosion. The same recommendations are made with regard to forestry operations.

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Appendix: Community Quality Evaluation and Management

Community Quality Defined

Managers at Eglin AFB, FL, have developed a system to classify community quality; "Ecological Tier System" (Department of the Air Force 1993). This system has also been used at Camp Blanding, FL (FNAI and TNC 1995). Determining community quality has obvious benefits for TES conservation planning. Low quality communities do not provide the same habitat quality for TES as higher quality communities, and therefore should be treated differently in terms of protection, restoration efforts, and allowable land uses. Use of a quality ranking system for management purposes can assure that protection priority is given to highest quality TES habitat. Furthermore, use of this system can assure that restoration activities are used for communities that have the potential to become high quality TES habitat with minimum restoration efforts. Similarly, use of a quality ranking system can ensure that efforts are not wasted in the restoration of low quality communities. Finally, plant communities on installations are subject to multiple land uses, and using a quality ranking system in combination with an assessment of impacts of various land uses can help managers determine which activities are appropriate in which communities, based on the potential to provide quality habitat for TES. The ranking system developed for Eglin AFB is provided in the following paragraphs (Department of the Air Force 1993).

TYPE I - High quality community: "Portions of vegetative communities which are in or closely approximate their natural state... These areas have experienced relatively few disruptive events. Examples are areas of old growth or relatively undisturbed vegetation. Management activities should be predominantly in the maintenance category, utilizing methods that mimic natural formative forces such as prescribed fire."

TYPE II - Intermediate quality community: "Portions of vegetative communities that still retain a good representation and distribution of associated species and which have been exposed to moderate amounts and intensities of disruptive events... These are areas where ecosystem function and viability can be restored through careful, responsible management. Management direction

will integrate appropriate management activities to accomplish restoration and maintenance objectives. Restoration activities may include practices that will accelerate change in the desired direction (i.e., use of herbicides, and/or mechanical methods of hardwood control, supplemental planting of longleaf seedlings)."

TYPE III - Moderately low quality community: "Portions of vegetative communities that do not retain a good representation and distribution of associated species and which have been exposed to severe amounts and intensities of disruptive events... These are areas where restoration of ecosystem function and viability might be possible, but would require significant and intensive management commitment over extended periods of time. Depending on land-use priorities, management direction may encourage a return to a more natural vegetative association over the long term and/or may include intensive use of traditional management techniques."

TYPE IV - Lowest quality community: "...sites that either will not be or are not capable of being restored under any likely realistic scenario because of dedicated land use. Type IV areas include cleared test ranges, sewage disposal spray fields, urban areas, main roads, designated clay pits, power line rights-of-way, and possibly some wildland interface areas."

In addition to giving a quality ranking to a community based on naturalness, managers may wish to use other parameters to determine what kind of activities should occur in communities, and which communities should be protected from certain activities. For example, presence of rare species, overall diversity, unusual species combinations, and diverse physical features (e.g., soil types, hydrologic regimes, and topographic situations) should be considered. Some systems consider all of these parameters and give a site a ranking based on them.

Data Requirements

To develop quality herbaceous seeps and wet savanna communities, and to practice sound ecosystem management while satisfying the goals of the military mission, protection of rare species, and production of forest commodities, installations should gather the following baseline information with which to make land use decisions:

- Locations and sizes of TES populations or significant natural features within communities.

- Mission land and resource needs to support the training or testing mission(s).

- Plant community identifications, and the juxtaposition of different communities within the landscape. Managers also should be aware of the relationship between plants and animals in each community and the habitats on which they depend. Identification of species and species-assemblages is essential in order to characterize within and between community diversity across watersheds and other landscapes. That is, once the ecological "uniqueness" of communities is determined, the most appropriate community based management can be determined. Moreover, knowledge about plant/animal life histories and plant-animal interactions can help managers plan activities that minimize disturbance to species of concern and overall community dynamics. For example, managers would want to avoid creating a barrier between upland terrestrial habitat for a rare animal species and the aquatic habitat it depends on for breeding.

- Quality and significance of plant communities on the installation. This information should be used to determine which communities have the highest priority for the conservation of TES species. Regardless of quality, the community may be highly significant based on rarity or uniqueness of the type.

- Natural processes that regulate communities and how they have been altered by human activities. It is not enough to identify all species in a community. Rather, processes that allow ecological succession to regress, stabilize, or accelerate must be identified in order to manage for the appropriate seral stage. Additionally, knowledge of processes allows for the development of ecological models, predictive tools enjoying a high degree of popularity in the fields of risk assessment and environmental impact analysis. Important processes include fire frequency, human land use patterns, wetland loss/gain, soil erosion, deforestation/reforestation, community recovery rates (from environmental perturbations), nutrient cycling, productivity, community succession and species replacement (exotic species introduction), population turnover, fecundity, and morality.

- Interagency cooperation and data compatibility/exchange. Arguably, interagency cooperation involving activities such as the sharing of information and leveraging of resources to achieve common goals may be among the most important elements in determining success with the ecosystem appoach. Cooperation is needed because few, if any, installations contain

closed ecosystems that support sustainable TES populations, and all are influenced by species and processes (hydrology, natural and human-induced impacts) occurring on adjacent lands. Moreover, state agencies and other natural resource-oriented groups often have in-house expertise, extensive libraries, access to a wealth of unpublished information, and can potentially provide much of the baseline information mentioned above. Not only can installations realize savings in time and money, but the citing of non-DoD sources may be viewed as more credible by the regulatory agencies and the general public.

Monitoring

Managers should monitor the effects of management practices on the communities or the features of interest. For the purpose of long-term monitoring, standardized sampling methods should be developed and used. Being able to quantify improvement or degradation of habitats over time is critical to making management decisions, as well as evaluating management practices. Methods as simple as establishing permanent plots or grids are useful for repeated surveys (Whitworth and Hill 1997). Geo-rectified aerial photographs can be useful in monitoring landscape and community changes over time. Keeping accurate records of land use is also important (e.g., detailed notes of fire occurrence and species response, as well as silvicultural techniques).

Monitoring on a microenvironment scale within an individual population may also reveal important information regarding the site requirements of that population. This information is especially useful in making management decisions for rare plant species. For a thorough description of methods for monitoring of a rare plant population and determination of its habitat requirements, including soil textural traits, moisture, soil chemicals, soil type, and light levels, see Boyd and Hilton's (1994) study of a population of *Clematis socialis*.

Acronyms

AFB	Air Force Base
DoD	Department of Defense
ESA	Endangered Species Act
FDNR	Florida Department of Natural Resources
FNAI	Florida Natural Areas Inventory
LCTA	Land Condition Trend Analysis
LRAM	Land Rehabilitation and Maintenance
NHP	Natural Heritage Program
SERDP	Strategic Environmental Research and Development Program
TES	threatened, endangered, and sensitive species
TNC	The Nature Conservancy
USACERL	U.S. Army Construction Engineering Research Laboratories
USFWS	U.S. Fish and Wildlife Service
WES	U.S. Army Engineer Waterways Experiment Station

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